2018

# Mathematics for engineering students in the 'Dual System': Assistance in study start-up and conduct

Derr, Katja Susanne

http://hdl.handle.net/10026.1/13323

http://dx.doi.org/10.24382/894

University of Plymouth

UNIVERSITY OF PLYMOUTH

# MATHEMATICS FOR ENGINEERING STUDENTS IN THE 'DUAL SYSTEM': ASSISTANCE IN STUDY START-UP AND CONDUCT

by

Katja Susanne Derr

A thesis submitted to the University of Plymouth

in partial fulfilment for the degree of

DOCTOR OF PHILOSOPHY

School of Computing, Electronics and Mathematics

Faculty of Science and Engineering

December 2018

PLYMOUTH UNIVERSITY

DRAKE CIRCUS, PLYMOUTH PL4 8AA

The Doctoral College

December 2018

# Acknowledgements

With this thesis I was able to combine the practical aspects of designing, developing, and evaluating a web-based learning environment with a fundamental theoretical analysis. I had the chance to broaden my knowledge on mathematics teaching in the domain of engineering, but also on statistics and test psychology. Thus throughout this project many people from different areas were involved to whom I would like to express my gratitude.

First of all, I would like to thank my supervisor Dr Mohammed Zaki Ahmed for his always constructive feedback, advice, and encouragement. I am also deeply grateful for the support of Professor Reinhold Hübl, my German supervisor and the *optes* project team leader at DHBW Mannheim. Further thanks go to Professor Holger Hofmann and Professor Steven Furnell who initiated the connection between the technical faculties at DHBW Mannheim and the University of Plymouth.

I would also like to express my gratitude to the examiners, Dr Jane Andrews, Dr Paul Davey, and Dr Toby Whitley; based on their comments this work was so much improved. At the outset of this project I greatly benefitted from the feedback offered by Ted Graham and Dr Colin Christopher. Furthermore, I want to thank Carole Watson at the Doctoral College for her always friendly and professional support.

Funding for this project was provided by the German Federal Ministry of Education and Research (BMBF) and it's "Quality pact for teaching". I would like to thank the *optes* project supervisor Professor Roland Küstermann for enabling this cooperation, furthermore Professor Dirk Saller who founded the *ZeMath* team at DHBW Mannheim and initiated the cooperation with *optes*.

Not being a mathematician I am extremely grateful for the input from my colleagues Magdalena Gottfried, Ulrich Huckenbeck, Edith Mechelke-Schwede, Tatyana Podgayetskaya, Christine Vandaele, and Miriam Weigel. Technical expertise came from my colleague Michael Stang - thank you for your patience! I also would like to mention the first year DHBW Mannheim students who shared their experiences by answering questionnaires and participating in interviews. Oliver Dreier in particular contributed to this project by developing a Moodle plugin for the diagnostic feedback. Further thanks go out to my former fellow students at the now much shrunk DHBW graduate team, especially Sabine Bakker Matejek and Vanessa Schimbeno for proof reading, and to Dr Anne Schreiber.

A very big special thanks goes to Dr Frauke Uekermann, for her proficient methodological feedback and for helping me to focus on the essentials. Last but not least I am thanking my family and friends for their constant and kind support - and for stopping to ask at some point. And of course MM.

# Author's declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Doctoral College Quality Sub-Committee.

Work submitted for this research degree at the University of Plymouth has not formed part of any other degree either at the University of Plymouth or at another establishment.

This study was carried out at Baden-Wuerttemberg Cooperative State University Mannheim (DHBW Mannheim) and financed with the aid of the joint research project optes, funded by the German Federal Ministry of Education and Research (BMBF) (ref. number 01PL17012).

**Publications and paper presentations:**

Derr, K.; Hübl, R.; Ahmed, M.Z (in print), "Monitoring the use of learning strategies in a web-based pre-course in mathematics. A comparison of quantitative and qualitative data sources", in: D. Ifenthaler, D.-K. Mah, J. Yau (Eds.) *Utilizing Learning Analytics to Support Study Success*, Springer International Publishing.

Derr, K.; Hübl, R.; Ahmed, M.Z. (2018), "Prior knowledge in mathematics and study success in engineering. Informational value of learner data collected from a web-based pre-course", *European Journal of Engineering Education Education EJEE*, Vol. 43 No 6, pp. 911-926, DOI: 10.1080/03043797.2018.1462765

Derr, K. (2017), "Identifying Consistent Variables in a Heterogeneous Data Set: Evaluation of a Web-Based Pre-Course in Mathematics." *Electronic Journal of e-Learning EJEL*, Vol. 15 No 1, pp. 82–93. ERIC Number: EJ1140127

Derr, K. et al. (2017), "Predicting study success in engineering? Evaluation of learner data" (Original title: Vorhersage von Studienerfolg in den Ingenieurwissenschaften über Learning Analytics? Aussagekraft von Lernerdaten in einem webbasierten Mathematik-Vorkurs, in U. Kortenkamp and A. Kuzle (eds.), *Beiträge zum Mathematikunterricht*, WTM, Münster, pp. 1297–1300. DOI: http://dx.doi.org/10.17877/DE290R-18569

Derr, K.; Hübl, R.; Podgayetskaya, T. (2016), "Potential and limitations to the use of formative e-assessment and automated feedback in online pre-courses" (Original title: Formatives eAssessment in Online-Brückenkursen: Potentiale und Grenzen und die Rolle des Feedback), in Institut für Mathematik und Informatik der Pädagogischen Hochschule Heidelberg (eds.), *Beiträge zum Mathematikunterricht*, WTM, Münster, pp. 1145–1148. DOI: http://dx.doi.org/10.17877/DE290R-17587

Derr, K.; Jeremias, X.V.; Schäfer, M. (2016), "(e)-bridging courses in mathematics: best practice reports from three universities" (Original title: Optimierung von E-Brückenkursen Mathematik: Beispiele von drei Hochschulen), in A. Hoppenbrock et al. (eds.). *Lehren und Lernen von Mathematik in der Studieneingangsphase*. Springer Spektrum, Berlin, pp. 115–129, ISBN: 978-3-658-10261-6

Derr, K.; Hübl, R.; Ahmed, M.Z. (2015), "Using test data for successive refinement of an online pre-course in mathematics". Proceedings 14th European Conference on e-Learning ECEL 2015, 29-30 October, Hatfield, pp. 173-180, ISBN: 978-1-910810-70-5

Derr, K.; Hübl, R.; Podgayetskaya, T. (2015), "Development of a web-based pre-course in mathematics based on formative evaluation" (Original title: Formative Evaluation und Datenanalysen als Basis zur schrittweisen Optimierung eines Online Vorkurses Mathematik), in N. Nistor and S. Schirlitz (eds.), *Digitale Medien und Interdisziplinarität; Medien in der Wissenschaft*, Band 68, Waxmann, Münster, pp. 186-196,
DOI: urn:nbn:de:0111-pedocs-113198, ISBN: 978-3-8309-3338-0

Derr, K.; Hübl, R.; Podgayetskaya, T. (2015), “Online assistance in mathematics pre-courses: domain-related and interdisciplinary aspects” (Original title: Betreuungskonzepte für Online-Vorkurse in Mathematik: Fachliche und überfachliche Aspekte), in Proceedings 2nd HD-MINT-Symposium, 24-25 September 2015, Nuremberg, pp. 64-69, ISSN: 1612-4537

Derr, K.; Hübl, R.; Podgayetskaya, T. (2015), “Online support in a pre-course in mathematics: approaches to addressing heterogenic groups” (Original title: Betreuungsangebote in einem Online Vorkurs Mathematik: Modularisierung als Antwort auf heterogene Studierendenschaft?), in F. Caluori, H. Linneweber-Lammerskitten and C. Streit (eds.), *Beiträge zum Mathematikunterricht*, WTM, Münster, pp. 228–231, DOI: https://doi.org/10.17877/de290r-16618

Derr, K.; Hübl, R. (2014), “Online pre-courses in mathematics” (Original title: Mathematik Studienvorbereitung Online für technische Studiengänge), in P. Morschheuser (ed.) *Qualifizierung von Studierenden im Student-Life-Cycle*, Proceedings Mosbacher Tag der Lehre, 23rd October 2014, Mosbach, pp. 104-109.

Derr, K.; Hübl, R. (2013), “Self-study university preparation in mathematics: didactical aspects of self-assessment” (Original title: Mathematik-Studienvorbereitung im Selbststudium: Didaktische Aspekte des Selbst-Assessment), in *Proceedings 1st HD-MINT-Symposium*, 7-8 November 2013, Nuremberg, pp. 138-143, ISSN: 1612-4537

Derr, K.; Hübl, R.; Ahmed, M.Z. (2013), “Web-based tests and learning material for study-preparation in mathematics for engineering programmes” (Original title: Online–Selbsttests und -Lernmaterialien zur Studienvorbereitung Mathematik), in *2nd khdm-conference Mathematik im Übergang Schule / Hochschule und im ersten Studienjahr*, 20-23 February 2013, University of Paderborn.

Derr, K.; Hübl, R.; Ahmed, M.Z. (2012), “University preparation via self-e-assessment & self-study: first findings and implications from evaluating an e-learning-platform”, in *Proceedings of ECEL 2012*, 11th European Conference on e-learning, 26-27 October 2012, University of Groningen, ISBN: 978-1-908272-74-4

Derr, K.; Hübl, R. (2012), “Online preparatory courses in Mathematics: Self-study courses for prospective students in engineering” (Original title: Studienvorbereitung Mathematik Online: Ein Selbstlernangebot für Studienanfänger/-innen in technischen Studiengängen), in M. Ludwig and M. Kleine (eds.), *Beiträge zum Mathematikunterricht*, WTM, Münster, pp. 189–192, DOI: http://dx.doi.org/10.17877/DE290R-8000

## Oral and poster presentations:

“Can we measure the influence of a pre-course in mathematics? Evaluation results from the optes project” (Original title: Welchen (messbaren) Einfluss hat ein Mathematik-Vorkurs? Evaluationsergebnisse aus dem Verbundprojekt optes), oral presentation *MINT-Kolleg Baden-Württemberg Tagung: Brücken ins Studium*, 21 March.2018, Stuttgart.

“Practice makes perfect? Mathematics from the point-of-view of engineering students” (Original title: Üben, üben, üben…? Mathematik aus der Sicht von Ingenieursstudierenden), oral presentation *Hanse-Kolloquium zur Hochschulmathematikdidaktik*, 10 November 2017, Göttingen.

“Measurement of learning gains in a web-based learning environement” (Original title: Lernerfolgsmessung in einem webbasierten Mathematikvorkurs), oral presentation *16th International ILIAS conference*, 14 September 2017, Freiburg.

“Informational value of learner data in a web-based course: relating self-tests, inventories, log files and study success” (Original title: Informationsgehalt von Teilnehmerdaten in einem webbasierten Vorkurs: Zusammenhänge zwischen Selbsttests, Fragebögen, LMS Logfiles und späterem Studienerfolg), oral presentation *12. Jahrestagung der Gesellschaft für Hochschulforschung GfHf*, 30 March 2017, Hannover.

Online study preparation in mathematics, poster presentation *DHBW Research day*, 5 Febuary 2015, Stuttgart.

“Ilias & mathematics”, oral presentation *SourceTalk Tage*, 27 August 2014, Mathematisches Institut Universität Göttingen.

“The optes project”, oral presentation *SourceTalk Tage*, 1st October 2013, Mathematisches Institut Universität Göttingen.

### The following external institutions were visited for consultation purposes:

Conference “Learning 4.0”, 28 April 2016, DHBW Villingen-Schwenningen.

Autumn conference working team “Didactic of mathematics in tertiary education” (Herbsttagung Arbeitskreis HochschulMathematikDidaktik), 27-28 November 2015, University of Applied Sciences, Geislingen-Nürtingen.

Spring school of educational measurement, 4-6 March 2015, University of Jena.

Autumn conference working team “Didactic of mathematics in tertiary education” (Herbsttagung Arbeitskreis HochschulMathematikDidaktik), 28-29 November 2014, University of Essen.

Workshop “Online assessment for first-year students” (Online-Assessment in der Studieneingangsphase), 17 July 2014, University of Duisburg.

DGfE (German Society for Education) Conference: Workshop Rasch modelling, 9 March 2014, Humboldt University Berlin.

11th International ILIAS conference 2012, Networking ILIAS - The Way To A Worldwide Campus, 6-7 September 2012, University of Stuttgart.

cosh meeting (cooperation between secondary and tertiary education), 27-29 Febuary 2012, Esslingen.

### Word count of main body of thesis:

Sixty-one thousand and twenty-one (61,021) words within the main body.

Signed ..........................................................................

Date ......................11th December 2018..................

**Katja Susanne Derr: Mathematics for engineering students in the 'Dual System': assistance in study start-up and conduct**


# Abstract

One major characteristic of the transition from secondary to tertiary education is the high heterogeneity of students' knowledge. In STEM-programmes, knowledge gaps in basic mathematics are considered one risk factor regarding graduation. One approach to this problem is the provision of preparatory courses in mathematics. The purpose of this mixed methods evaluation study was to identify factors supporting "at risk" students' successful pre-course participation and transition to university. This issue was addressed using quantitative and qualitative evaluations carried out with six cohorts of engineering students at Baden-Wuerttemberg Cooperative State University Mannheim.

Using the theory of self-regulated learning as a theoretical framework this thesis analysed the interplay between students' preconditions, their learning behaviour, and the learning environment. The quantitative analyses revealed a dominant influence of cognitive variables, results in a diagnostic test being the strongest determinant of first year mathematics achievement. Pre-course learning gains had a moderating effect on this relation and an increase in gain score (pre-post-test difference) could be related to an increase in students' first year mathematics exam.

The analyses of learning behaviour suggested that for the evaluation of successful learning processes of "at risk" students other variables are relevant than for the rest of the student body. Attitude towards mathematics or students' use of time management and organisational strategies, for example, did not affect learning gains of this group and were identified as covariates of prior domain knowledge. Only one variable significantly contributed to explaining why "at risk" students obtained higher pre-course gain scores. The number of self-tests a student had submitted correlated with learning gains and even showed a significant impact on first year performance in mathematics.

The study also showed that this group of learners highly benefits from external structuring and guidance. A comparison of additional support programmes revealed much more learning activities and higher learning gains for participants in an e-tutored course than for participants in a less structured face-to-face version. Avoiding self-monitoring activities could be identified as an additional risk factor for students with poor domain knowledge.

Deviations from the quantitative model suggested that high learner engagement not necessarily results in increased first year performance. A set of interviews with first year students helped to understand counterintuitive results and clarify why even students with "ideal" data profiles sometimes struggle in their first year at university. It was shown that "at risk" students are less able to seek help and to benefit from peer learning.

Based on the analyses carried out in this thesis a set of recommendations for the design of preparatory courses in mathematics are made that are considered highly relevant for practitioners in the field of study preparation, e-learning and learning analytics.

# Contents

Glossary and abbreviations ..... v

Illustrations and tables ..... vii

1 Project background and study interest ..... 1

1.1 Practical relevance of the research question ..... 3
1.2 Theoretical approach ..... 4
1.3 Structure of the thesis ..... 5

2 Literature review ..... 7

2.1 The mathematics problem ..... 7
2.1.1 Basic skills in mathematics – a decline? ..... 8
2.1.2 Predictors of academic achievement ..... 12
2.1.3 Pre-courses in mathematics ..... 15
2.1.4 Transition to tertiary education ..... 21
2.1.5 Characteristics of engineering education ..... 23
2.1.6 Conclusion ..... 27
2.2 The learning process ..... 29
2.2.1 Theoretical framework of self-regulated learning ..... 30
2.2.2 Social constructivism and situatedness of learning ..... 32
2.2.3 Experiential learning and learning styles ..... 33
2.2.4 Conclusion ..... 36
2.3 The learner (person | self) ..... 37
2.3.1 Cognition and metacognition ..... 37
2.3.2 Affective factors and attitudes ..... 39
2.3.3 Conclusion ..... 43
2.4 Learning behaviour ..... 45
2.4.1 Use of learning strategies ..... 46
2.4.2 Approaches to learning ..... 51
2.4.3 Conclusion ..... 57
2.5 The learning environment (design) ..... 59
2.5.1 E-learning ..... 59
2.5.2 Learning analytics ..... 71
2.5.3 Tools to support self-regulation ..... 75
2.5.4 Formative assessment to initiate and monitor learning ..... 79
2.5.5 Conclusion ..... 87
2.6 Conceptualisation of student learning ..... 89
2.6.1 Measurement of attitude towards mathematics ..... 89
2.6.2 Measurement of learning strategy use ..... 92
2.6.3 Measurement of prior domain knowledge and learning gains ..... 95
2.7 Gap in knowledge and contribution to theory ..... 101

3 Conceptual framework ..... 105

4 Methodology ........ 111
4.1 Pre-study sub-research questions ........ 112
4.2 Main study sub-research questions ........ 113
4.3 Methodological approach ........ 119
4.3.1 Action-based research ........ 119
4.3.2 Design-based research ........ 119
4.3.3 Case-based research ........ 120
4.3.4 Summary ........ 121
4.4 Rationale for a mixed methods research approach ........ 123
5 The studies ........ 129
5.1 Descriptive analyses ........ 129
5.2 Pre-study ........ 135
5.2.1 Study design and data collection ........ 135
5.2.2 Sample ........ 137
5.2.3 Ethical considerations ........ 138
5.2.4 Results: Course design ........ 139
5.2.5 Results: Pre-post-test design ........ 153
5.2.6 Summary and discussion ........ 173
5.3 Main study ........ 175
5.3.1 Study design ........ 175
5.3.2 Data collection ........ 178
5.3.3 Sample ........ 179
5.3.4 Ethical considerations ........ 181
5.3.5 Quantitative results ........ 183
5.3.6 Qualitative results ........ 211
6 Summary and discussion ........ 225
6.1 Summary ........ 225
6.2 Discussion ........ 229
6.3 Limitations and methodological discussion ........ 233
6.4 Recommendations for practice ........ 235
6.5 Recommendations for future research ........ 239
6.6 Conclusion ........ 241
7 References ........ 243

# List of Appendices


## A Publications

1-14 Publications and paper presentations

## B Descriptive data

B.1 Pre- and main study (2011-2016)

B.2 Main study (2014): Course types

## C Quantitative tools: pre-posttest design

C.1 Pre-test items

C.2 Post-test items

## D Surveys

D.1 Demographic and personal variables

D.2 Self-reports on mathematical areas

D.3 Attitude towards mathematics

D.4 Evaluation questionnaire

D.5 Learning strategies scale

## E Pre-study: group interviews

E.1 Group interviews 2012

E.2 Group interviews 2013

E.3 Guiding questions

E.4 Extract: group interview statements

## F Quantitative analyses

F.1 Relations between exam scores and cumulated GPA (2011)

F.2 Mathematics I performance pre-course participants versus non-participants (2011-2016)

F.3 Multiple regressions with Mathematics I (2011-2016)

## G First year student interviews

G.1 Guiding questions

G.2 Interview summaries

G.3 Categorisations

Note: German expressions that could not be translated to English as they refer to the German educational system are italicised.

# Glossary and abbreviations

Expressions and abbreviations related to the German education system

| | |
|---|---|
| *Abitur* | highest German secondary school degree, allows progression to university (= *Allgemeine Hochschulreife*); comparable to A-level, or the International Baccalaureate Diploma |
| AHR | *Allgemeine Hochschulreife,* certificate that allows progression to university; comparable to A-level, or the International Baccalaureate Diploma; granted by school types "*Gymnasium*" and "*Berufliches Gymnasium*" |
| ASI | Approaches to Studying Inventory ({Entwistle 1983 #729}) |
| ATMI | Attitudes Toward Mathematics Inventory ({Tapia 2004 #217}) |
| ATMLQ | Attitudes to Technology in Mathematics Learning Questionnaire ({Fogarty 2001 #305}) |
| *Berufliches Gymnasium* | Subject-related German secondary school type leading to *Abitur* (AHR) but focusing on technical or economic subjects (in this report referred to as S-GYM) |
| FH | *Fachhochschule,* German university of applied sciences, or technical university |
| FHR | *Fachhochschulreife*, German secondary school degree that allows progression to universities of applied sciences (FH) and cooperative universities (DHBW) |
| *Fachoberschule, Berufsfachschule* | German secondary school types leading to FHR (access to some universities) (in this report referred to as Vocational school) |
| *Gymnasium* | General German secondary school type leading to AHR (unconditional access to all universities) (in this report referred to as G-GYM) |
| ACT | American College Testing (US), standardised test; provides admission to undergraduate programmes (topics: English reading, mathematics, and science); www.act.org |
| ARS | Audience Response System (clicker lectures) ({Mazur 1997 #715}) |
| Blackboard | licensed learning management system, widely used in the United Kingdom (www.blackboard.com) |
| BMBF | *Bundesministerium für Bildung und Forschung*; Federal Ministry of Education and Research |
| CAA | Computer assisted assessment |
| CBA | Computer based assessment |
| CLT | Cognitive load theory ({Sweller 1998 #379}; {Sweller 2005 #97}) |
| CSCL | Computer-supported collaborative learning |
| DHBW | *Duale Hochschule Baden-Württemberg* (Baden-Wuerttemberg Cooperative State University); Students at this type of university are employed and spend 50% of their courses of study at their place of work. DHBW degrees are B.A. and B.Sc. |
| CEDEFOP | European Centre for the Development of Vocational Training |

| | |
|---|---|
| GCSE | General Certificate of Secondary Education (United Kingdom) |
| GPA | Grade Point Average |
| HEI | Higher Education Institution |
| ILIAS | Open Source LMS, widely used in Germany (www.ilias.de) |
| ILS | Inventory of Learning Styles ({Vermunt 1988 #1959 }) |
| LASSI | Learning and Study Strategies Inventory ({Weinstein 1988 #1667}) |
| LIST | *Lernstrategien im Studium*, German version of the MSLQ addressing learning strategies of university students ({Schiefele 1994 #676}) |
| LMS | Learning Management System |
| MARS | Mathematics Anxiety Rating Scale ({Richardson 1972 #517}) |
| MINT | *Mathematik, Informatik, Naturwissenschaft*, *Technik*; German acronym, similar to 'STEM' |
| Moodle | Open Source LMS, widely used in Germany and the United Kingdom (www.moodle.org) |
| MOOC | Massive Open Online Course |
| MSLQ | Motivated Strategies for Learning Questionnaire ({Pintrich 1990 #455}) |
| MTAS | Mathematics and Technology Attitudes Scale ({Pierce 2007 #309}) |
| OLAT | Open Source LMS (Online Learning and Training), University of Zurich (www.olat.org) |
| PDF | Portable Document Format |
| SDT | Self-Determination Theory ({Ryan 2000 #530}) |
| PISA | Programme for International Student Assessment |
| SAT | standardised test (US College Board, Educational Testing Service); provides admission to undergraduate programmes (topics: writing, critical reading, and mathematics); https://collegeboard.org/sat |
| SPQ | Study Process Questionnaire ({Biggs 1976 #726}) |
| SRL | Self-Regulated Learning |
| STEM | Science, Technology, Engineering, Mathematics; similar to German acronym 'MINT' |
| TIMSS | Trends in International Mathematics and Science Study |

Mathematical test items

| | |
|---|---|
| simplistic problem | mathematical problem represented by a term or equation |
| word problem | mathematical problem that is embedded in a text / related to a practical application (descriptive problem or story problem) |
| worked solution | feedback to a mathematical exercise that provides a detailed stepwise solution |
| worked-out example | exemplary stepwise solution to a mathematical problem, usually preceded by a general explanation of the mathematical principle and followed by exercises asking the student to reproduce this solution |

# Illustrations and tables

## List of figures

*Figure 1 Thesis overview* 6

*Figure 2 A triadic analysis of self-regulated functioning (Zimmerman, 1989a, p. 330)* 30

*Figure 3 Relational model of the dynamics between affect, cognition and social environment in the regulation of the personal learning processes (Malmivuori, 2001, p. 296)* 31

*Figure 4 Phases and processes of self-regulation as modelled by Zimmerman and Moylan (2009), p. 300* 45

*Figure 5 Item characteristic curve ICC for an item with a difficulty estimate of β=.5 (the probability of being solved is 50% for a participant with the ability level of .5)* 98

*Figure 6 ICCs for two items with high (left) and low (right) discriminatory power* 99

*Figure 7 Conceptual framework: effects of pre-course participation on "at risk" students' first year performance* 106

*Figure 8 Research design and data collection pre-study and main study* 129

*Figure 9 Overview of the pre-course design (*the face-to-face courses were added in 2012, the e-tutoring courses were added in 2014)* 140

*Figure 10 Screenshot of the diagnostic pre-test (three multiple choice items plus web-based calculator widget)* 141

*Figure 11 Diagnostic pre-test results 2012 per mathematical field in per cent (n = 642)* 143

*Figure 12 Screenshot of revised diagnostic feedback: average entry-test results of previous cohort: Overall, six basic categories, four additional categories (translated from German original)* 144

*Figure 13 Screenshot of learning module (6) Trigonometry* 146

*Figure 14 Screenshot learning module "Equations", practical example optical lenses* 150

*Figure 15 Screenshot learning module "Squares, roots, and logarithms", practical example exponential function* 151

*Figure 16 Screenshot self-test learning module "Equations"* 151

*Figure 17 ICCs, Item characteristic curves, for Percentages item (pre-test), first version in 2011 and 2012 and revised version in 2013 and 2014* 159

*Figure 18 Pre-test Rasch difficulty estimations (β) in 2013 and 2014, per item, ordered per category: 1 Arithmetic (10 items), 2 Equations (9 items), 3 Powers, roots, logarithms (9 items), 4 Functions (9 items), 5 Geometry (9 items), 6 Trigonometry (9 items), 7 Logic (8 items), 8 Vectors and linear algebra (8 items), 9 Continuous functions and limits (6 items)* 163

*Figure 19 Post-test Rasch difficulty estimations (β) in 2013 and 2014, per item, ordered per category: 1 Arithmetic (5 items), 2 Equations (5 items), 3 Powers, roots, logarithms (5 items), 4 Functions (4 items), 5 Geometry (5 items), 6 Trigonometry (5 items), 7 Logic (4 items), 8 Vectors and linear algebra (4 items), 9 Continuous functions and limits (3 items)* 163

*Figure 20 Pre-test-post-test mean scores / ability scores 2013 and 2014, participants both tests (group A) and participants post-test only (group B)* 166

*Figure 21 Boxplots pre-test mean scores / ability scores θ 2011-2014 (participants both tests)* *170*

*Figure 22 Boxplot post-test mean scores / ability scores θ 2011-2014 (participants both tests)* *170*

*Figure 23 Pre- and post-test results 2014: participants both tests (n = 603) in comparison to participants post-test only (n = 105)* *193*

*Figure 24 Pre- and post-test results 2014 complete dataset in comparison to number of test attempts (n = 603)* *202*

*Figure 25 Pre- and post-test results 2014: complete dataset in comparison to chosen pre-course type (n = 603)* *204*

*Figure 26 Conceptual framework: effects of pre-course participation on "at risk" students' first year performance, summary of study outcomes* *227*

## List of tables

*Table 1 Different factors related to the framework of self-regulated learning* 36

*Table 2 Relationships between the referential and structural aspects of students' approaches (from Crawford et al., 1994, Table 4, p. 338)* 53

*Table 3 Approaches to learning in the field of engineering (Case and Marshall, 2004, p. 613)* 56

*Table 4 Examples for attitude towards mathematics items, addressing confidence, feelings, engagement, and value* 91

*Table 5 Overview of variables related to the learner and the use of learning strategies in the web-based pre-course in mathematics* 106

*Table 6 First year students per degree programme 2011 to 2016* 130

*Table 7Number of pre-course participants per year* 130

*Table 8 Number of male / female first year engineering students 2011 to 2016* 130

*Table 9 Overview of quantitative variables pre-study* 136

*Table 10 Sample overview pre-study* 137

*Table 11 Overview of item parameter estimates used for item analysis* 155

*Table 12 Classical and IRT statistics for arithmetic item, with D = item-total correlation, β = Rasch difficulty estimates, MNSQ = fit statistics, t-test fit statistics (all estimated by ConQuest), and Wald test (estimated by eRm) (*not answered = 0 score)* 158

*Table 13 Number / percentage of not answered items in "Vectors and linear functions" (first set: item 33-36; second set: item 67-71)* 161

*Table 14 Overview of design revision process 2011-2014* 164

*Table 15 Database for item analysis 2011-2014* 165

*Table 16 Pre-test-post-test mean scores / ability scores 2013 and 2014, participants both tests (group A) and participants post-test only (group B)* 167

*Table 17 Pre-test mean scores / ability scores θ 2011-2014 (participants both tests)* 169

*Table 18 Post-test mean scores / ability scores θ 2011-2014 (participants both tests)* 169

*Table 19 Overview of quantitative variables main study* 176

*Table 20 Study interests and data collection methods* 178

*Table 21 Sample overview main study* 180

*Table 22 Study success and withdrawals of the 2011 cohort, participants of at least one test (pre- or post-test) (n = 715) (*missing values in GPA = did not take any examination = withdrawal)* 183

*Table 23 Significant correlations between examination results and final year GPA (grade point average), 2011 cohort per degree programme (p < .01 for all correlations)* 184

*Table 24 Single linear regression on dependent variable GPA (grade point average) with independent variable Mathematics I (reverse coded)(2011: n = 660; 2012: n = 779; 2013: n = 665); *p < .001* 185

*Table 25 Binary logistic regression on dependent variable GPA (grade point average) with independent variable Mathematics I (reverse coded) (2011: n = 660; 2012: n = 776; 2013: n = 665); *p <.001* 186

*Table 26 Regression analysis for variables predicting Mathematics I (n = 465). Model A: Students' preconditions when entering university; Model B: Diagnostic pre-test score added* 188

*Table 27Mathematics I pass rate and grades of 2014 pre-course participants (n= 578) versus non-participants (n=96) (missing / first year withdrawals: n = 34)* 192

*Table 28 Hierarchical regression analysis for variables predicting Mathematics I (n = 465). Model B: students' preconditions when entering university versus Model C gain score added* 194

*Table 29 Attitude towards mathematics subscales "LM Liking Mathematics" and "SCLM Self-confidence in Mathematics"(Kadijevich, 2006; Mullis et al., 2012)* 196

*Table 30 Time management and organisational strategies MSLQ subscales (Pintrich et al., 1991)* 198

*Table 31 Time on task and effort-related variables* 200

*Table 32 Online learning activities* 201

*Table 33 Pre-course gain score 2014: "At risk" students (n = 315) versus "not at risk" students (n = 288) and number of self-tests* 202

*Table 34 Overview of different course types 2014* 203

*Table 35 Pre- and post-test results 2014 and resulting gain score: complete dataset in comparison to chosen pre-course type (n = 603)* 204

*Table 36 Pre-course gain score 2014: "At risk" students (n = 315) versus "not at risk" students (n = 288) in the different course types* 205

*Table 37 Pre-course evaluation: Application of mathematics items* 207

*Table 38 Hierarchical regression analysis for variables predicting Mathematics I (n = 465). Model B: students' preconditions when entering university versus Model C gain score added, Model D number of test attempts added* 209

# 1 Project background and study interest

Between 2000 and 2010 numerous efforts were made to interest German secondary school graduates in studying engineering. Eventually the number of first-year students in STEM[1] degree programmes did increase (Autorengruppe Bildungsberichterstattung, 2012; Koppel, 2013) but this positive trend was accompanied by a significant increase in student withdrawals. In 2011, German degree programmes in electrical engineering, mechanical engineering, or computer science had drop-out rates of 30% at universities of applied sciences, and up to 48% at "traditional" universities (Heublein *et al.*, 2012). Quite similar developments have been reported from the Netherlands (van den Bogaard, 2012) and the United Kingdom. Although attrition rates in general are lower in the UK there is a considerable difference between the average across all degrees (8% in 2011) and courses in engineering and computer science (15% in 2011) (HEFCE, 2013).

While student withdrawal is a complex problem and usually influenced by many different factors the failure to meet the demands in mathematics has been identified as one reason for not completing a STEM degree (Heublein *et al.*, 2009). Mathematical grounding is a prerequisite to understanding university mathematics, which in turn is necessary to successfully study in this area. Many undergraduates are prepared for these demands, but an increasing number appear to lack basic skills in mathematics, suggesting a growing diversity in educational backgrounds (Crowther *et al.*, 1997; Bescherer, 2003; Lawson, 2003; Henn and Polaczek, 2007). As a consequence, more and more universities address this problem by offering additional mathematics support.

At Baden-Wuerttemberg Cooperative State University (subsequently abbreviated as DHBW for Duale Hochschule Baden-Württemberg), the impact of student heterogeneity has long been felt less strongly, mainly due to a more rigorous selection process performed by the university's corporate partners (students are also employees and graduation is part of their employment contracts). Drop-out rates

[1] STEM = Science, Technology, Engineering, Mathematics; similar to German acronym MINT

differ among degree programmes and DHBW locations[2] but traditionally were below average (Kramer *et al.*, 2011). In the last decade, however, the number of student withdrawals in the dual system increased and in 2011 drop-out rates for the first time exceeded 10% (DHBW Präsidium, 2012, p. 30–30). Thus a need for more support was identified for DHBW students, as well, especially in technical degree programmes.

In order to respond to these challenges an interdisciplinary team, ZeMath, was founded at DHBW Mannheim in 2009. Its goal was to develop learning material that allowed prospective students to recapitulate the basic secondary school curriculum before their courses of studies began. In 2010 the project started with a paper and pencil entry-test for all technical degree programmes[3], eight learning modules provided as PDF-files, an online post-test and an evaluation questionnaire. Based on the first year's experiences it was decided to extend the material and develop a comprehensive web-based preparatory course programme.

In 2012, the project was incorporated into the joint research project *optes*, funded by the German Federal Ministry of Education and Research BMBF (www.optes.de). The BMBF "quality pact for teaching" aims at the homogenisation of first year students' knowledge, the improvement of the student experience in the transition from secondary to tertiary education and, on a larger scale, the increase of retention rates. Just like optes, many of the funded projects address the mathematics problem by providing preparatory programmes (see BMBF online database www.qualitaetspakt-lehre.de). It is quite unclear, however, if the provision of short-termed remedial courses can solve the complex problem of first year student heterogeneity, and if it does, what variables drive this effect. Taking an evaluative view this thesis explores this problem under the overarching research question:

> How does participation in a web-based pre-course in mathematics impact first year tertiary performance of "at risk" students?

[2] DHBW has nine locations in the Southern part of Germany (Heidenheim, Heilbronn, Karlsruhe, Lörrach, Mannheim, Mosbach, Ravensburg, Stuttgart, Villingen-Schwenningen).

[3] Computer science, electrical engineering, mechanical engineering, mechatronics, and industrial engineering

## 1.1 Practical relevance of the research question

The evaluation of preparatory programmes has been found methodologically challenging. By attempting to demonstrate how the course supported, or failed to support, first year students' successful transition to university, this study addresses a highly relevant practical issue.

In Germany, preparatory courses are not embedded into the tertiary curriculum and students are free to participate or to withdraw at any time, resulting in biased or incomplete data sets. Such inconsistencies may even be increased in web-based environments which, compared to traditional face-to-face courses, are characterised by poorer learner commitment (Ashby *et al.*, 2011; Smith and Ferguson, 2005; Street, 2010) and lower answer rates (Cook *et al.*, 2000; Fan and Yan, 2010; Tourangeau *et al.*, 2013). As a consequence, most evaluations of non-mandatory, extra-curricular pre-courses lack comprehensiveness and fail to clearly identify the effects of pre-course participation.

This study addressed this practical problem by building a data model that (a) identified a lack in basic mathematics knowledge as a risk for subsequent study success in engineering, (b) showed the impact of pre-course participation on this risk, including the influence of course design and learning behaviour, and (c) controlled for influential factors like educational background or prior knowledge.

While prior or subsequent performance can be represented by grades, exam scores, or grade point average (GPA), participants' learning behaviour, their activities on the platform and the outcomes of these efforts are much more difficult to quantify (see also next section). Many learning management systems allow tracking online activities but it is unclear how such data can contribute to explaining learning outcomes. This study aimed at objectively measuring learner behaviour and then triangulated results with qualitative analyses of the student experience. Based on these observations it was possible to clarify if and how data collected from web-based pre-courses can contribute to the emerging field of learning analytics (Greller and Drachsler, 2012; Scholes, 2016).

## 1.2 Theoretical approach

> "Student learning is a complex phenomenon. Multiple and interactional sources of variation need to be considered, and the relationships between individual differences in learning behaviour and student learning outcomes are typically neither simple nor linear." (Meyer and Eley, 1999, p. 197)

The overall goal of this thesis was to make suggestions for the design of web-based preparatory courses, accounting for the heterogeneity of participants. In order to make such recommendations the different variables related to successful pre-course participation had to be identified. This was done within the framework of self-regulated learning, which, based on Bandura's social cognitive theory, acknowledges the complexity of the learning process and the interrelatedness of cognitive, metacognitive, behavioural and environmental factors (Boekaerts *et al.*, 2000; Zimmerman, 2002).

Self-regulated learning has been found a fruitful theory for explorative research as well as large scale evaluations of secondary and tertiary achievement and it also has been found viable for the analysis of learning processes in e-learning environments (Kaleidoscope seed project, 2007). According to Azevedo, self-regulated learning provides a theoretical framework that accounts for learner characteristics (e.g. prior knowledge, age, or gender), technical and environmental features (e.g. access to different representations of information), and mediating learner behaviour (e.g., metacognitive skills, use of learning strategies) "while also considering how these various aspects interact" (Azevedo, 2005, p. 200).

In emphasising these interactions, self-regulated learning is linked to other theoretical approaches to learning, namely social constructivism and approaches to learning. Social constructivist approaches stress the situatedness of learning and focus on interactions between learner and environment (Palincsar, 1998; Lave and Wenger, 1991). Learner's individual conceptions and approaches to learning are highly relevant for the outcomes of the learning process, but the environment may reinforce or subdue the development of self-regulation skills and of a deep and understanding-oriented approach to learning (Marton *et al.*, 2005a).

While self-regulation is needed for every learning process it is of particular relevance for open learning environments that give access to a large amount of learning material. Students have to navigate the material, make decisions about their individual learning goals, plan and structure the learning process, and finally evaluate the outcomes. It has been suggested that high achieving students are more likely to make effective use of such strategies (Pintrich and de Groot, 1990; Kramarski and Gutman, 2006) whereas students who are new in a domain or struggle with its cognitive demands will also find it difficult to self-regulate.

A higher level of guidance, either technologically or by (human) tutors, may positively affect learning outcomes of novices and of students with poor domain knowledge (Winters *et al.*, 2008). Thus different course designs are needed for different groups of students. Considering the correlations between domain knowledge and variables related to effective self-regulation it is unclear, however, how the “at risk” group’s benefit from design elements can be evaluated.

The underlying theoretical problem thus was to differentiate between effects of prior domain knowledge, learning behaviour, and environment in the understudied context of pre-courses in mathematics and to show if learning gains of at “risk students” could be related to the design of the course.

## 1.3 Structure of the thesis

The research interest was addressed by an iterative approach, comprising several phases of design, analysis, and evaluation. Figure 1 shows an overview of the different parts of the thesis. This introduction will be followed by a review of the relevant literature (chapter 2) which will lead to the conceptual framework (chapter 3) and methodology (chapter 4).

Chapter 5 describes the two studies that were conducted: a pre-study with the overall goal to build the course design and the tools needed for the quantitative investigations (5.1) and a main study that, based on pre-study outcomes, addressed the overarching research question (5.2). The results are reported separately and chronologically in chapter 5.1.6 and 5.2.6. Chapter 6 summarises and discusses all study outcomes with respect to their contribution to theory and practice.

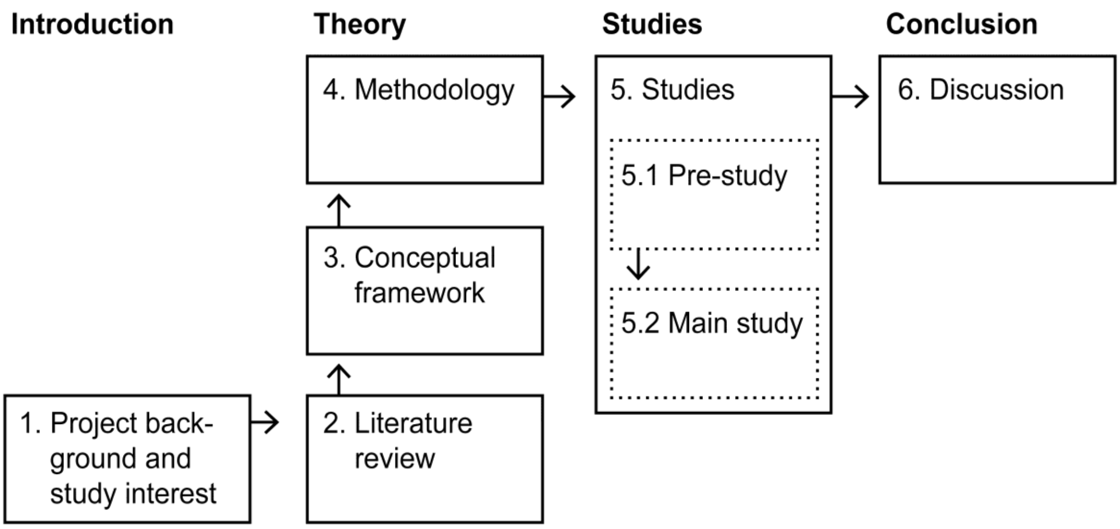



*Figure 1 Thesis overview*

# 2 Literature review

The first part of the literature review gives an introduction to the research problem and its context, from an introduction of the so-called “mathematics problem” to its relevance for academic success to the practice of providing and evaluating pre-courses in mathematics at engineering faculties.

Section 2.2 describes the theoretical framework of this study that also provides the general structure of the following chapters. In section 2.3 factors related to the person that are relevant in the model of self-regulated learning are introduced. Section 2.4 focuses on learning behaviour, the use of learning strategies and students’ approaches to learning. In chapter 2.5 the main part of the literature review, the impact of design on learning outcomes is discussed. Methods to operationalise affective, metacognitive and cognitive variables are summarised in section 2.6. The literature review is concluded with a discussion of the gap in knowledge identified (section 2.7).

## 2.1 The mathematics problem

> “While the need for science undergraduates and graduates to demonstrate greater proficiency in quantitative skills is acknowledged internationally, so is the deficit in students’ basic mathematical skills” (Tariq, 2013, p. 779)

The “mathematics problem” was first addressed in 1995 in a joint report by the London Mathematical Society, the Institute of Mathematics and its Applications, and the Royal Statistical Society (Howson *et al.*, 1995). The authors claimed that not enough students were interested in studying mathematics, science and engineering, and that those who did were not adequately prepared for mathematics at higher education level. Many first year students appeared to be unable to perform essential computations, let alone solve problems that consisted of several steps. Furthermore, these deficits were accompanied by an overall “changed perception of what mathematics is - in particular of the essential place within it of precision and proof.” (Howson *et al.*, 1995, p. 3).

### 2.1.1 Basic skills in mathematics – a decline?

In 2000, the UK Engineering Council stated that students entering tertiary education with the goal to graduate in mathematics, science or engineering were “hampered by a serious lack of essential technical facility - in particular a lack of fluency and reliability in numeric and algebraic manipulation and simplification” (Engineering Council, 2000, p. 1). The report referred to statements from lecturers and instructors as well as to results from diagnostic tests taken during induction week at UK universities, indicating a decline in mathematical competence of secondary school graduates. Lawson (2000) collected evidence for this development by comparing the results of a diagnostic entry-test at Coventry University over a timespan of several years. He could show that students with the same grades in mathematics in 1991 outperformed their successors in 1997 in almost all mathematical categories. For example, in 1991 nearly all students with A level mathematics, grade C, were able to identify the graph of the cosine function, while in 1997 only 54% in this group of students could do so. To some extent, this development could be related to syllabus changes and restructuring of the secondary school system, in combination with a decrease of students choosing A level mathematics, but the decline also affected other mathematical fields, like fractions, or powers and roots.

Similar observations were made by Faulkner *et al.* (2010) who analysed mathematics entry test results of nearly 5,000 first year Irish students between 1998 and 2008. They found that the overall decrease in test scores was not so much caused by a general decline in mathematics but by a growing number of students with lower secondary school qualifications enrolling in science and technology programmes. As the test results of A level students had remained relatively stable over the years, the authors attributed the lower test scores to a bigger and thus more heterogeneous student body.

In Germany, as well, access to tertiary education was opened for a larger part of the population (Statistisches Bundesamt, 2012; Statistisches Bundesamt, 2014; Middendorf *et al.*, 2013). The German educational system is characterised by high variability, with differing school types in the different federal states. In the course of the Bologna process standards were harmonised; to date, four major paths lead to an undergraduate course in engineering: (1) The “traditional” path via *Gymnasium* and *Abitur* (a graduation that allows progression to all German universities); (2) Graduation with *Abitur* from a subject-related secondary school (*Berufliches Gymnasium*, focused on either technical or economic subjects); (3) Graduation from a secondary school leading to *Fachhochschulreife*, a certificate that allows studying at Universities of Applied Sciences only, and (4) Vocational training and experience in a study-related professional field. For these applicants, the ability to study in higher education needs to be assessed in an additional examination.

Considering the different educational backgrounds of German first year students, it may not come as a surprise that their knowledge levels differ, sometimes significantly. In addition, the mathematical abilities of students with *Abitur* appear to have decreased. Schwenk and Berger reported results from a longitudinal study conducted at TFH (*Technische Fachhochschule*) Berlin in 1995, 2000, and 2005, comparing mathematical entry-test results of first year engineering students. While the number of first year students nearly tripled in the observed time-frame (from 329 in 1995, to 877 in 2005), the test means showed a linear decline, with finally not one student of the 2005 cohort reaching the full score (Schwenk and Berger, 2006, p. 37). Participants were clustered according to the type of secondary school they had graduated from; an especially strong decline was observed for those who had graduated with *Fachhochschulreife*. The authors concluded that, in the light of these results, instructors in tertiary education should reconsider the standards they expect from secondary students (Schwenk and Berger, 2006, p. 40).

Polaczek and Henn conducted a similar study at FH (*Fachhochschule*) Aachen. They analysed entry-test results of first year students in 2005, 2006, and 2007. The researchers had confined the mathematical topics covered by the test to the basic curriculum of sixth to tenth grade, and predefined a test score of 70% as essential for successfully participating in first year engineering lectures. The average test result, though, was around 43%. A decline of performance in the investigated period of time was not observed, but again a significant difference between students who had graduated from *Gymnasium* and those with *Fachhochschulreife* became apparent. This was contrasted by students’ mathematics grades, as students with

*Fachhochschulreife* in average had better grades, but scored poorer in the test (Polaczek and Henn, 2008, p. 3). The overall study goal was to investigate the relations between entry qualification and study success. Eventually, out of those study participants who scored less than 40% in the entry-test, only one could reach the second semester without failing an essential examination. All in all the authors stated that domain-specific prior knowledge (as measured through entry-test results) was found a valid predictor of success in the first year of study (Henn and Polaczek, 2007; Polaczek and Henn, 2008).

While the above named authors attributed the decline in mathematics to the deficits of students with certain secondary school degrees (namely *Fachhochschulreife*), Knospe (2011) suggested that the revised and abridged German school syllabus caused students' lack in basic mathematical skills. In his analyses of diagnostic test results from 2002 until 2010 at several German universities of applied sciences he found significant differences between students who had attended an advanced mathematics course (*Leistungskurs*) at school and those who had not (see also Greefrath *et al.*, 2014). Type of secondary school in this study had a visible but not significant influence on test results (Knospe, 2008; Knospe, 2011).

These reports indicate that students' prior knowledge level in mathematics indeed has changed, but there also seem to be different dimensions to the mathematics problem; lacking a longitudinal, nation-wide analysis of first year engineering student's mathematical knowledge in Germany it might be hasty to talk of a decline. It could also be argued that curricular changes made in secondary schools have not yet been acknowledged by tertiary education (Dürrschnabel *et al.*, 2013). Therefore diagnostic entry-tests, or mathematics examinations, demand mathematical skills that in secondary education are no longer taught, or are taught differently. Furthermore, the fact that a higher percentage of secondary school graduates are entering higher education might have led to different distributions in the reported test results, as lower performing students simply would not have been participating ten years earlier.

It also should be stated that heterogeneous knowledge levels have been observed in secondary education, as well. One characteristic of the outcomes of the "Programme for International Student Assessment PISA" was the high variance in fifteen year old students' knowledge, not only between the participating OECD countries but within them, as well. Germany, for example, had above-average standard deviations in 2006 and 2012 (Frey *et al.*, 2008; Sälzer *et al.*, 2013) with similar group sizes at both ends of the mathematics knowledge scale (17.5 % "excellent", versus 17.7% "very poor" and "at risk") (Sälzer *et al.*, 2013, p. 74). Heterogeneous results were also reported for the "Trends in International Mathematics and Science Study TIMSS", suggesting that large differences in mathematics knowledge already become noticeable in primary school (Köller *et al.*, 2002). In a German national assessment study, Pant *et al.* (2013) reported large differences between fourth grades students' knowledge levels depending on federal states. According to this study, an average primary school student from the German federal state of Saxony had a lead of two years over an average student from the city state of Bremen (Pant *et al.*, 2013, p. 405).

Such analyses suggest that the decline in mathematics knowledge might rather be an increase in heterogeneity and that differences between students are perpetuated over a longer period of time.

The "mathematics problem" thus has been discussed from different perspectives. From a curricular point of view it has been suggested, for example, that more communication was needed between secondary and tertiary institutions. For the federal state of Baden-Württemberg a group of educators from different school systems and university engineering faculties proposed a joint mathematics curriculum to be used as a reference for both mathematics teachers and university lecturers (cosh cooperation schule:hochschule, 2014). Similar suggestions have been made by the European Society for Engineering Education SEFI with a Core Zero curriculum for engineering students (SEFI mathematics working group, 2013).

In Germany it also has been discussed to prolong study duration for students who do not meet the demands, an approach that has been piloted at Stuttgart University and

Karlsruhe Institute of Technology (KIT) (Röhrl *et al.*, 2013) and that might lead to a "zeroth" semester, comparable to foundation courses in the UK.

Even the revision of the engineering mathematics curriculum has been suggested, taking into account the changing profile of the engineering profession. To be successful as an engineer today requires a set of competencies, e.g. organising, planning, communicating, and working in interdisciplinary teams, with everyone focusing on different elements of the overall production process. Therefore it might be over-conservative to demand mathematical skills that could perfectly be performed by a computer, and validated by a specialist (Kent, 2002). This point of view has been vehemently rejected by educators and engineers who warn of adjusting requirements downwards and aligning them to a lower prior knowledge level. According to Scanlan, engineers can only be competent in applying models in the physical world when they completely understood these models mathematically (Scanlan, 1985, p. 446). From that perspective the "calculess engineer" is not an option (Stevens, 2003) and ignoring the importance of mathematical understanding for nearly every aspect of an engineer's daily work would mean "confusing engineers with fitters" (ibid.).

Whereas this argument is on-going, it can be agreed upon that today's engineering students often lack basic skills in mathematics and therefore struggle in their first year at university. The next section will take a closer look at the predictive quality of mathematics knowledge for subsequent study success in this area.

### 2.1.2 Predictors of academic achievement

Significant relations between prior and subsequent performance are well established in educational research, also referred to as "Matthew effect" (Hattie, 2009, p. 41). In a meta-analysis of 800 meta-analyses on the effectiveness of teaching and learning, Hattie described prior achievement as the strongest and most consistent predictor (with an average effect size of $d$ = 0.67).

Mathematics grades in particular have been found good predictors of study success. Parker (2005), for example, examined the influence of scores on a mathematics placement test on retention rates at a North American university college. Students with low test scores not only were less successful in their subsequent mathematics exams, they also more often left university without having gained a degree.

Faulkner *et al.* (2010) observed an increase in students failing first year mathematics exams in a science and technology degree programme in Ireland. In a follow-up study the authors wanted to identify predictors of failure in “service” mathematics. They analysed the influence of a set of variables potentially related to mathematics achievement at university. The only statistically significant variables in their data model were mathematics achievement at school and results in a diagnostic test in mathematics. Thus students lacking prior knowledge in mathematics appeared to be “at risk” to fail mathematics and to withdraw from their degree programme. As a limitation to their study the authors reported a high number of missing data, especially in the group they were interested in (non-traditional students).

Not always do test scores correlate as strongly with measures of study success. In a longitudinal study, Budny *et al.* (1998) analysed 28 cohorts of engineering students of an US American university. In their model, the best predictor of graduation was first year GPA, outperforming scores in the standardised placement test in mathematics (Math SAT, https://collegeboard.org/sat).

Kokkelenberg and Sinha (2010), as well, investigated characteristics of STEM students at a North American university, based on data from six cohorts of engineering students. They found that both prior knowledge in mathematics and high school GPA significantly influenced academic achievement. Other significant variables were gender, ethnicity, and college experience.

Zhang *et al.* (2004) evaluated the impact of students’ preconditions (demographic and prior achievement) on retention in engineering programmes. Data from nine US American universities were analysed; for six universities complete data sets were available to perform similar multiple logistic regressions. The results showed that graduation rates at these universities significantly depended upon high school GPA and on scores in the standardised Math SAT. The role of other predictors, like gender, ethnicity, or citizenship, varied among institutions and appeared to interact with the two consistent variables. Prior achievement thus can be considered a strong predictor, but other reasons for study success should be taken into account. The multiple model in this study, for example, explained only 13% of the variation in student graduation, indicating that many other variables are needed to precisely "predict" graduation in engineering (Zhang *et al.*, 2004, p. 319).

From an educational psychologist perspective the influence of psychosocial variables and their interaction with "traditional" predictors need to be accounted for; meta studies by Robbins *et al.* (2004) and Richardson *et al.* (2012) demonstrate the importance of affective and motivational variables for tertiary achievement.

Robbins *et al.* (2004) conducted a meta-analysis of 109 studies, evaluating correlations between psychosocial variables and academic achievement (indexed by cumulated GPA). Psychosocial and study skill factors (PSFs) were clustered in nine constructs, from general self-concept to achievement motivation to contextual influences; the cognitive predictors high school GPA and SAT scores were also entered in the model. Not surprisingly, both traditional measures were found significant and strong predictors of academic achievement in all of the reviewed studies; the two non-traditional variables self-efficacy and achievement motivation, however, showed similar impact on cumulated GPA. The multiple model accounted for 26% of the variance in GPA (traditional predictors alone: $R^2$ = 22%; PSF only model: $R^2$ = 16%) (Robbins *et al.*, 2004, p. 275, table 11).

Richardson *et al.* (2012) reviewed 217 publications and compared the influence of traditional predictors like high school GPA and standardised test scores (SAT and ACT) to five groups of non-traditional predictors (personality traits, motivational factors, self-regulatory learning strategies, students' approaches to learning, and psychosocial contextual influences) (Richardson *et al.*, 2012, p. 355). The authors suggested a combined non-traditional model (effort regulation, test anxiety, academic self-efficacy, and grade goal) that accounted for 20% of the variance in tertiary GPA. This model, however, did not outperform the contribution of the two traditional variables; high school GPA and test scores alone accounted for 22% of the variance in GPA.

An even stronger influence of traditional variables was found for STEM-related subjects. Ackerman *et al.* (2013) analysed data sets of 589 undergraduate students, performing multiple linear regressions with cumulated GPA, and logistic regressions with attrition rates. In both models they entered SAT scores, high school GPA, placement test scores, and batteries of metacognitive variables, referred to as five trait complexes. Cognitive variables in all single and multiple models significantly influenced academic achievement. Placement tests in mathematics particularly contributed to explaining cumulated GPA (isolated $R^2$ = .21), thus being nearly as predictive as high school GPA and SAT scores together ($R^2$ = .23). Trait complexes in isolation added another 5-8%, leading to a total variance explained in cumulated GPA of 40%. For prediction of attrition, the authors found comparable relations and a total variance explained of 37%, although the placement tests in mathematics were less powerful in these models (isolated $R^2$ = .11). The authors suggested that, next to traditional predictors like high school GPA and standardised test results, students' self-concepts in mathematics (self-confidence and attitudes towards the subject) and their ability to master and organise learning most strongly contributed to predicting achievement in STEM. They also found that these trait complexes interacted with gender.

Concluding it can be stated that, although other variables have been found important, prior achievement in general (as measured by secondary GPA) or in a domain-related subject are stable predictors of subsequent study success. Mathematics grades and mathematics placement test results have been found highly relevant for STEM (and other) subjects. Knowledge gaps in mathematics therefore indeed can be considered a threat to study success in engineering.

### 2.1.3 Pre-courses in mathematics

Based on such considerations, universities have started to provide additional educational activities. In the 1990s primarily large technical universities offered summer courses introducing students to higher mathematics. Today, pre-courses in mathematics have become as much the rule as the exception. In 2011, the "Quality Pact for Teaching" was initiated by the Federal German Government, funding projects to improve higher education with two billion euros. 125 of the 186 projects listed in the BMBF online database can be related to the areas “transition from secondary to tertiary education” and “introductory phase” (www.qualitaetspakt-lehre.de). Many of these projects address the mathematics problem by providing preparatory or bridging courses, consisting of one or more weeks of basic mathematics. Other projects focus on support during the first weeks or months of the degree programme.

Common to all these projects is their high diversity regarding course designs, goals, and evaluation practice. By definition, preparatory courses are extra-curricular activities. Organisation and administration thus varies between institutions, as does the funding. In the following section some exemplary projects will be presented and discussed.

Meiner and Seiler (2009) conducted a short survey on participation rates in mathematics face-to-face pre-courses at eleven German universities. Though the data only provided a spotlight and were difficult to compare across projects the summary revealed that no course lasted longer than three weeks (most courses lasted five days) and that only the lesser part of prospective engineering students was reached by these courses. The most striking result was that drop-out rates in some pre-courses were up to 57%, suggesting an overall weak commitment of participants.

TFH (*Technische Fachhochschule*) Berlin offers a face-to-face pre-course for first year engineers that takes place in the week preceding induction. For their evaluation study they compared entry-test results of participants (roughly a third of each cohort) and non-participants. The former reached higher entry-test results but the authors claimed that many weaker students (who might have needed this additional programme most) did not attend. As the study did not comprise pre-/ post-test comparisons these observations were quite limited and only allowed to suggest further needs for investigation (Schwenk and Berger, 2006, p. 38).

The study by Polaczek and Henn (2008) also lacked pre- or post-test analyses; the impact of the remedial course was measured by analysing entry-test results of all first-year students. The authors pointed out that only participants who had taken A level mathematics courses (*Leistungskurs*) at secondary school showed significant improvements in comparison to their counterparts who had not attended the mathematics pre-course (Polaczek and Henn, 2008, p. 16).

A more elaborate example of a blended learning project reported from a joint project at Kassel University, with participation of the University of Darmstadt and the University of Paderborn (Biehler *et al.*, 2012). The course addresses students from different faculties but has been used by engineers as well. The provided online resources consist of several learning modules that are structured along units, e.g. overview, introduction to the domain, information, application, typical mistakes, and exercises. Learners are provided short diagnostic pre- and post-tests for each module. The learning material can be used in two blended learning scenarios, the first a face-to-face course using e-learning resources, and the second an e-learning course offering sporadic face-to-face meetings. For his dissertation, Fischer investigated into students' learner behaviour in this pre-course, in relation to course choice, personal variables, and performance (cf. Fischer, 2014). While pre-test results for both groups were similar, students who had participated in the e-learning version performed slightly better in the post-test, but not significantly, indicating that both versions had a comparable impact on learning outcomes (Biehler *et al.*, 2012, p. 1975).

Another online pre-course was developed by the KTH Royal Institute of Technology (*Kungliga Tekniska högskolan*) in Stockholm (Krumke *et al.*, 2012; Roegner *et al.*, 2012). Since its introduction more than ten years ago, the programme has been used by eight Swedish universities. In 2010, a pilot study at four German universities of applied sciences was conducted (RWTH Aachen, TU Braunschweig, TU Kaiserslautern, and TU Berlin), furthermore at Imperial College, London. Since 2012, the University of Bologna is using the course, as well. The programme combines online learning material and a mathematics call centre operated by mathematics tutors. The e-learning course consists of two parts: (1) Arithmetic, Algebra, Roots and logarithms, trigonometry, and mathematics notation, and (2) differentiation, integration, and complex numbers. Every module starts with e-learning resources (texts, exercises, and examples), followed by exercises, self-tests, and a short exam. The three items of this exam have to be solved correctly in order to pass the module; additionally a written homework has to be submitted. Tutors monitor the learning progress, give feedback on submitted tasks and suggest participation in learning groups. Students are also given tasks to be discussed in forums and submitted as group work.

The four German universities participating in this pilot implemented the material in their existing face-to-face pre-course programmes. An evaluation study by Roegner *et al.* (2012) with 1,269 engineering students revealed that the online courses were highly appreciated by most participants, especially when combined with face-to-face courses that referred to the same material (Krumke *et al.*, 2012 p. 5). A limitation to this study was that no pre-tests were administered, therefore learning outcomes could not be evaluated. The overall goal of this study had been to increase the pass rate in “Linear Algebra 1”. Most students who had attended both courses, online and face-to-face, achieved this goal; furthermore, participants of the online course performed better (plus 12%) than those who did not participate at all. Against expectations, the group with the lowest results in “Linear Algebra 1” were students who had participated in the face-to-face pre-course only (Roegner *et al.*, 2012, p. 13–13).

Experiences with the above named project were incorporated in a European web-based platform now managed by a spin-off e-learning company (MUMIE online math education, www.mumie.net; this company also provides the web-based pre-course OMB+, www.ombplus.de, which can be used by partner universities throughout Germany). However, only the University of Delft performed a comprehensive evaluation study with Aerospace Engineering and Computer Science students who participated in the MUMIE pre-course. Pre-course participants outperformed non-participants in their first linear algebra exam, particularly when they had been classified “active participants” based on their activities on the platform (Vuik *et al.*, 2012).

Greefrath *et al.* (2014) and Greefrath *et al.* (2016) investigated the impact of pre-course participation on mathematics exam grades of electrical engineering and computer science students at two German universities (FH Aachen and University of Kassel). In this study, participation in the pre-course programme led to better results in a placement test at both universities, but only in Aachen an effect of pre-course participation on exam scores could be observed. The authors suggested that the effect of the pre-course was not strong enough to overpower the role of prior knowledge in mathematics. Both the results in a pre-test and participation in A-level mathematics courses were very strong predictors in their model. As the study lacked information regarding students' learning activities or their learning gains in the pre-course the authors were unable to differentiate between these factors and make causal relations between pre-course participation and study success.

It can be seen from these examples that the literature on preparatory courses is very broad, with various perspectives, sample sizes, and datasets. Different universities use different approaches and course designs, and only randomly are course participation, mathematics test results or pre-course learning gains related to academic achievement. Pre-courses or bridging courses are often project-funded, thus not integrated into the university's administration. Technical barriers and data privacy policies thus may prohibit a connection with student data.

In smaller studies it can be easier to access more comprehensive data. Johnson and O'Keeffe (2016), for example, evaluated the effects of a mathematics bridging course on non-traditional students. Based on the observations of Faulkner *et al.* (2010), the goal of the study was to increase the retention rates of adult students and improve their mathematical self-efficacy. Participants of this course indeed showed lower withdrawal rates but the groups were not randomised, the samples were very small (between 7 and 29), and non-participants' preconditions were not investigated or controlled for. Thus the difference between participants and non-participants might as well have stemmed from differing prior knowledge levels and could not be ascribed to the intervention.

Evaluations are certainly easier when courses are formally integrated into the degree programme. Two UK-based studies by Lagerlöf and Seltzer (2009) and Di Pietro (2012) quite thoroughly evaluated the impact of remedial mathematics courses on academic achievement in economic sciences. Students were assigned to these courses based on their results in a placement test and participation was compulsory. Both studies failed to find significant effects of course participation on student performance. Lagerlöf and Seltzer (2009) could confirm that secondary school grades in mathematics were strong predictors of academic achievement and that in the remedial group only students with relatively good school grades were able to benefit from the course. Several US-American evaluation studies supported the impression that remedial courses often fail to close the gap between poor and high performing students (Moss and Yeaton, 2006; Calcagno and Long, 2008; Bettinger and Long, 2009). Ballard and Johnson (2004) even suggested that participation in a (mandatory) remedial mathematics course significantly predicted poor achievement in a course in microeconomics.

Commenting on the lack of correlation between exam scores in a remedial course in mathematics and subsequent academic achievement, Clark and Lovric (2009) pointed out that such programmes could even negatively affect students' academic careers by giving those who had performed well a false sense of security. These somewhat sobering results show that the provision of additional courses not necessarily solves the mathematics problem. They also show the difficulty to quantify the effects of remedial courses against the strong influence of prior knowledge and prior performance. If students' knowledge gaps are as serious as suggested, it may be questionable if they can be closed in a couple of weeks (or even days) and if pre-courses are much more than the "mathematical version of sticking plaster." (Mustoe, 2002, p. 237). The literature indicates that remedial courses may fail to address the group with the biggest learning needs; the following section therefore explores other factors that may be relevant in the context of preparatory courses for engineering students.

### 2.1.4 Transition to tertiary education

Prior knowledge in mathematics, or the lack thereof, plays an important role in engineering education. However, other factors may need to be considered, as well. Closing gaps in a knowledge area may be a matter of hours if students only need to recapitulate or “reactivate” some techniques. But students with considerable knowledge gaps may need a lot of effort and have to do this in an already demanding phase. In the following section research on the first year experience will be discussed in relation to the mathematics problem.

Besterfield-Sacre *et al.* (1997), for example, showed that not only poor grades make students leave engineering programmes. They reported a multiple regression model, including demographic background, mathematics knowledge, high school GPA and an inventory addressing students’ attitudes and interest in engineering. $R^2$ for this model was .29, the remaining amount of unexplained variance suggesting that a considerable number of students left the course in spite of good performance. It was found that these students’ attitudes towards engineering were less positive, they also lacked self-confidence regarding their mathematics and science abilities compared to persisting students. Based on these observations, the authors developed a programme to improve the learning experience of this group of “good” but disinterested and unsatisfied engineering students (Besterfield-Sacre *et al.*, 1998).

An earlier study by the same authors suggested a considerable decrease in motivation during engineering students’ first year at university (Besterfield-Sacre *et al.*, 1996). Similar observations were made by Shaw and Shaw (1997) who clustered engineering students’ attitudes towards mathematics and found that about a third would move from an initially positive attitude to an outright dislike of the subject at the end of their course.

To some extent such developments have been ascribed as “concomitants” of the first year experience at tertiary institutions (Harvey *et al.*, 2006). In this period students are most likely to re-adjust their expectations and decide to change subject, university, or career plans. However, the first year experience in itself can become an influential factor if perceived as stressful or even overwhelming.

Students entering higher education are confronted with a multitude of new and sometimes intimidating demands. They have to orient themselves in an unfamiliar environment, get to know their peers and lecturers, interact with administration, or adapt to living in an unknown city. In addition, they must cope with new learning contents and different teaching styles, often characterised by a higher pace and a lower level of individual support (Pampaka *et al.*, 2012).

The first year experience, or transition phase, thus has been treated as a research field in its own right, particularly in the United Kingdom (Yorke and Longden, 2008; Ecclestone *et al.*, 2010), the United States (Pascarella and Terenzini, 1991; Al-Holou *et al.*, 1999), and Australia (Krause *et al.*, 2005; Kift *et al.*, 2010). In Germany this phase in tertiary education has only recently come into focus; students' problems, however, appear to be quite similar. In a qualitative analysis of students' descriptions of the demands of the transition phase Bosse and Trautwein (2014) identified four main categories, from content-related to personal to organisational to social (Bosse and Trautwein, 2014, p. 50). The authors claimed that personal problems, like managing and structuring one's schedule, as well as organisational issues, like understanding the university's mechanisms, were much more influential than cognitive problems.

Research could also show that social aspects play an important role for students' ability to cope with the new environment. Students may experience that staff are not available (Krause *et al.*, 2005) or that they are not seen as individuals (Harvey *et al.*, 2006), resulting in a lack of engagement (Yorke and Longden, 2008). One important part of the transition to university is, however, that students learn to actively seek contact or ask for help. Students who find it difficult to socially integrate or to interact with lecturers and professors may also find it hard to build a sense of belonging (Thomas, 2012).

It therefore has been suggested to develop a "transition pedagogy" that is concerned with the problems of the increasingly heterogeneous student body entering tertiary education (Kift *et al.*, 2010). According to the authors, the key strategies in improving the first year experience (FYE) are to develop a first year curriculum that helps students to become engaged and active learners, to provide access to both learning and life support, to foster a sense of belonging, and to build academic-professional partnerships (Kift *et al.*, 2010, p. 11). Similar suggestions were made by Hockings *et al.* (2010), with a strong focus on individual differences between students.

Student engagement and belonging was also addressed by the Student Retention & Success programme. Its final report summarised the implementation of remedial projects at universities across the UK, from institutional changes to staff development to the implementation of new learning and teaching practices that foster collaboration and communication skills (Thomas, 2012).

The multitude of approaches demonstrates the complexity of the “transition problem” and that not one most relevant factor can be singled out. Interactions between individual and institutional conditions may even result in “chain reactions”, as shown in the interview study by Bosse and Trautwein (2014). They gave the example of a science student who experienced her first year as highly demanding, particularly regarding mathematics. She thus was glad to find a study group; however, this group dissolved after a couple of weeks so that she had to search for a new one. She then failed her first mathematics exam and came under additional pressure because she was at risk to lose funding. This example reveals the interrelatedness of different aspects of the transition phase; it also shows, however, that *if* first year students experience subject-related problems these are likely to occur in the field of mathematics and statistics (Bosse and Trautwein, 2014, p. 54f.)

### 2.1.5 Characteristics of engineering education

The multiple organisational, personal, and individual challenges of the first year experience most probably apply to all students entering tertiary education. In the domain of engineering, however, students more often claim to feel ill-prepared for the demands of their course, particularly in the field of mathematics (Krause *et al.*, 2005; Bargel, 2015).

To some extent these problems can be related to the fact that mathematics is a subject all students know from secondary school; different approaches and teaching styles then can easily result in feelings of alienation. Particularly mathematics majors are confronted with highly unfamiliar forms of doing mathematics (Dieter, 2011) and "the transition from informal to formal language and reasoning is certainly one of most common cognitive problems that students experience when learning mathematics" (Clark and Lovric, 2009, p. 764).

In STEM-related fields mathematics teaching may be less abstract, but nevertheless students perceive a gap and an increase in pace and cognitive demands. Pampaka *et al.* (2012) compared first year students' perceptions of the transition phase, with a focus on the mathematics learning experience. In this study, entering students with high levels of mathematics self-efficacy were more likely to think of the transition phase as a positive experience. It could also be shown that engineering and mathematics students more often perceived the gap between secondary and tertiary education as very broad and, compared to medicine and chemistry students, more often were unhappy about this change.

In a longitudinal study exploring students' perceptions of the value of mathematics for their degree, Harris *et al.* (2015) observed that STEM students often were (negatively) surprised by the high amount of mathematics in their course. The authors also found that many first year students failed to make a connection between their mathematics lectures and the rest of the curriculum. Examples from the engineering context given by the "transmath" project thus were greatly appreciated by students.

In 1999, Armstrong and Croft analysed engineering students' knowledge and confidence in basic mathematics and, based on their observations, made some recommendations for improvement. Next to preparatory courses and support centres for first year students they suggested developing mathematics learning material for engineers that would help staff to make connections between theory and practice. It indeed is an often reported criticism that "service" mathematics are detached from the learning contents they should "serve", resulting in demands for integrated curricula in engineering education (Gill and O'Donoghue, 2008). According to Booth (2008), doing mathematics in today's engineering contexts demands a form of understanding that goes beyond the knowledge of theorems and algorithms. Students should be encouraged to reflect on their learning experience. By integrating the subject of mathematics into other lectures reflection could be fostered and students would be enabled to develop an understanding of "mathematics in the experienced world of engineering." (Booth, 2008, p. 389).

Thus not only students' problems with mathematics, but a lack of integrative and activating approaches to teaching mathematics has been suggested to cause student withdrawal in engineering. Research could show that students and staff benefit from integrated courses, collaborative design projects, or programme and faculty development projects (Froyd and Ohland, 2005; Besterfield-Sacre *et al.*, 2014), but it seems that in science and engineering, compared to other disciplines, traditional teaching styles prevail (Litzinger *et al.*, 2011; Ferrare and Hora, 2014).

A review of the literature on change projects in engineering education by Tolley and Mackenzie (2015) indicated that change sometimes is difficult to implement; in 191 articles they found only modest evidence that innovation projects had lasting effects on faculty and teaching styles. Vogt (2008), as well as Gasiewski *et al.* (2012) suggested that STEM faculties were reluctant to "embrace active learning practices", particularly in introductory courses. As observed by Gill and O'Donoghue in their analysis of teaching practice in "service" mathematics, the use of relevant real-life mathematical examples was unanimously "acknowledged as being important" but also was "invariably absent." (Gill and O'Donoghue, 2008 , p. 5). Considering the high workload in engineering courses (Kolari *et al.*, 2008) many lecturers may simply lack the time to try out alternative teaching approaches or to develop meaningful mathematics examples.

The traditionally high engineering workload and the (perceived or actual) lack of time might also affect engineering students' learning behaviour and lead to strategic approaches to learning. Meyer and Eley (1999) observed that first year engineering students' approaches to learning mathematics were mainly focused on exam performance. They also found that during the first year students' attitudes towards mathematics significantly decreased. They suggested that either the high workload in the engineering course had evoked this behaviour, or that engineering students were mainly interested in the application of mathematics in real life and therefore not attracted by the university's theoretical approach.

Based on observations made at the University of California, Brint *et al.* (2008) found that student engagement and approaches to learning were distinctly different between academic disciplines. While in arts, humanities and social sciences students would focus on interaction, participation, and sharing ideas, students in natural sciences and engineering would show a much stronger focus on improvement of skills and more often consider the relevance of their learning activities for the job market. Other studies suggested that engineering students would prefer "traditional" learning techniques like reading, practicing, and studying alone over strategies like elaborating, seeking further information, or discussion with peers (Litzinger *et al.*, 2011; Gainsburg, 2015). An earlier study by Lumsdaine and Lumsdaine (1995) even suggested that engineering students dreaded team work.

Such generalisations of the engineering education environment have been contrasted by projects that aim at building learning communities. Olds and Miller (2004) could show that the introduction of a first year integrated curriculum to a particular group of students not only affected their satisfaction with the course but also resulted in lower withdrawal rates. Kendall Brown *et al.* (2009), as well as Young *et al.* (2011) reported the implementation of integrated curricula programmes, comprising social activities but also the provision of practical examples that helped connecting engineering with mathematics. These studies showed that participants highly benefitted from these programmes and developed a stronger sense of belonging than students who did not participate.

### 2.1.6 Conclusion

In this first section the research problem, the “lack of preparedness” in mathematics (Croft *et al.*, 2009, p. 109), was set out in its context and its relevance for tertiary achievement. It was shown that the “mathematics problem” becomes visible in an increasing inhomogeneity of students entering engineering degree programmes, a situation instructors and students have to face.

Several assumptions have been made regarding the reasons for the decline in mathematics, or the increase in heterogeneity. Tertiary education has been opened for a broader range of applicants with “non-traditional” backgrounds (Faulkner *et al.*, 2014) and for students who attended vocational schools (Polaczek and Henn, 2008; Greefrath *et al.*, 2014; van Soom and Donche, 2014). These students appear to be less prepared for the demands of tertiary education, whereas the knowledge level of “traditional” students remained more or less unchanged. Other authors observed a general decline, caused by a revised school syllabus with less interest in or time for the development of basic skills (Lawson, 2000; Knospe, 2011). A third approach relates the widening access to higher education to a higher rate of less qualified students (Tolciu and Sode, 2011), suggesting a decline in “college readiness” and extending the problem to metacognitive skills (Venezia and Jaeger, 2013).

Concluding, gaps in basic (Armstrong and Croft, 1999) or “extremely basic” (Ballard and Johnson, 2004) mathematics knowledge and skills can be considered a risk factor regarding study success in engineering. Discovering that these gaps exist and trying to close them puts additional strain on students in an already demanding situation. In the transition phase students have to cope with social, organisational, and financial issues, many of them for the first time in their lives. Compared to other tertiary programmes, engineering courses demand a high workload from students, and each gap in basic knowledge adds to this workload. It therefore seems reasonable to move additional mathematics support to pre-courses that take place in the “liminal phase” between secondary and tertiary education (Clark and Lovric, 2008, p. 35), and the growing number of participants in preparatory and bridging courses throughout Germany reveals that students embrace this support (Bargel, 2015).

At the same time, extra-curricular settings have their own peculiarities. Students feel less obliged to participate on a regular basis and are more likely to withdraw (Meiner and Seiler, 2009; Bausch *et al.*, 2014). Particularly students with broad knowledge gaps and students who lack the ability to learn independently thus may not benefit from such courses (Mustoe, 2002).

The review also demonstrated the difficulties to evaluate the effects of remedial programmes in a meaningful way. The data collected from pre-courses often miss important information, like educational backgrounds, prior performance, or comparisons between prior knowledge and pre-course outcomes. Furthermore, organisational and technical barriers or university secrecy obligations in many cases prohibit relating pre-course data to tertiary performance.

For this thesis it was possible to collect comprehensive anonymised data sets of several cohorts of engineering students and to analyse correlations and interactions between them. The following chapters will explore the different influential aspects related to “at risk” students’ participation in a web-based preparatory course in mathematics.

## 2.2 The learning process

In this section, the theoretical foundations are laid that help to explain successful and less successful (e-) learning and (self-) study processes. The theoretical model of self-regulated learning is introduced and its viability with other theoretical approaches is demonstrated.

First of all, the role of the "self" in the learning process might need some clarification. As pointed out by Straka (2005), it is not possible to study without participation of the student, or his or her "self". The emphasis has been found useful, however, to acknowledge individual differences between learners, their perceptions of the learning environment, and their actions within it. In the course of the Bologna process the shift from "teacher-centred to student-centred learning" has been formulated as the central concept of tertiary education (Kehm, 2010, p. 44; ESG, 2015, p. 12). According to this concept, knowledge is no longer "transmitted by lecturers", but actively constructed by students who discuss their thoughts with peers, collaborate and make use of different tools and technical devices. Internet and e-learning environments provide students with opportunities to organise and pace their learning process independently. As a result of "E-Bologna" (Wildt, 2005) students are not only allowed but expected to take over responsibility for the management of this process, and the importance of self-direction or self-regulation increases. In the OECD "Programme for International Student Assessment PISA" self-regulated learning, like problem solving, is defined as a cross-curricular competence (Baumert *et al.*, 2000, p.15).

Terms like "student-centred", "self-directed", and "self-regulated" learning refer to different scientific discourses. Whereas the first is related to the above named constructivist "shift from teaching to learning" (Halford and Lea, 2014), self-direction is mainly used in the context of lifelong learning, focussing on adult learners and their pursuit of individual learning goals (Knowles, 1975). Finally, self-regulated learning is a conceptual framework describing the interplay between cognitive, metacognitive, and affective aspects of learning which is based in educational psychology (Zimmerman, 1989b; Boekaerts *et al.*, 2000). This chapter investigates the potential of self-regulated learning as a "guiding theoretical framework to examine learning with hypermedia" (Azevedo, 2005) and relates it to other models that focus on the interrelatedness of learning processes, namely social constructivism (Palincsar, 1998; Lave and Wenger, 1991) and approaches to learning (Marton *et al.*, 2005a; see section 2.4.2).

### 2.2.1 Theoretical framework of self-regulated learning

> "... to be successful in online courses, it helps to be a highly motivated, self-regulated learner." (Artino and Stephens, 2009, p. 146)

Self-regulated learning is rooted in educational psychology and refers to the works of Bandura's social learning theory. His model of social cognition describes the reciprocal relations between the individual, their behaviour, and the environment (Bandura, 1977a; Bandura, 1977b). Human behaviour, and thus learning, is determined by these three interacting factors (see Figure 2). According to Zimmerman, learners are "self-regulated to the degree that they are metacognitively, motivationally, and behaviorally active participants in their own learning process" (Zimmerman, 1989b, p. 4).

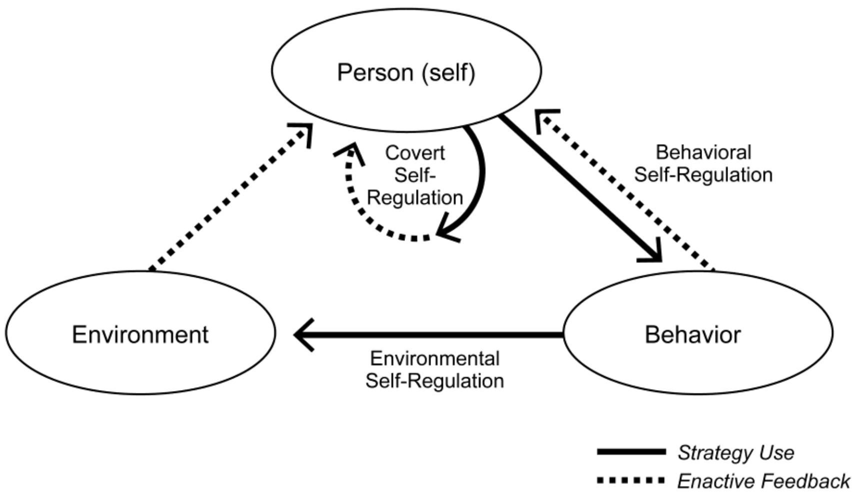



*Figure 2 A triadic analysis of self-regulated functioning (Zimmerman, 1989a, p. 330)*

Students' ability to self-regulate has been found correlated with academic achievement (Pintrich and de Groot, 1990; Kramarski and Gutman, 2006), indicating that "students who are able to regulate their learning effectively are more likely to achieve specific learning goals.” (Artelt *et al.*, 2003, p. 10). It is acknowledged that learning is an active, situated and context-dependent process, and students that use efficient strategies to organise and structure this process are more likely to be successful.

Alternative theoretical concepts of self-regulated learning have been developed, for example, by Pintrich and de Groot (1990) and Pintrich (2000; 2003) who focused on the role of motivation and goal orientation for subsequent learning behaviour.

For the field of mathematics learning Malmivuori (2001) emphasised the role of students’ self-beliefs and self-perceptions which were fundamental for their motivation to engage in learning mathematics. She could show that students constantly interpret their experiences in the learning environment and, based on these interpretations, feel more or less able to “do mathematics”. In the dynamic interplay between affect, cognition and social environment affect thus emerged as an integral component of cognition and self-reflection (cf. Figure 3).

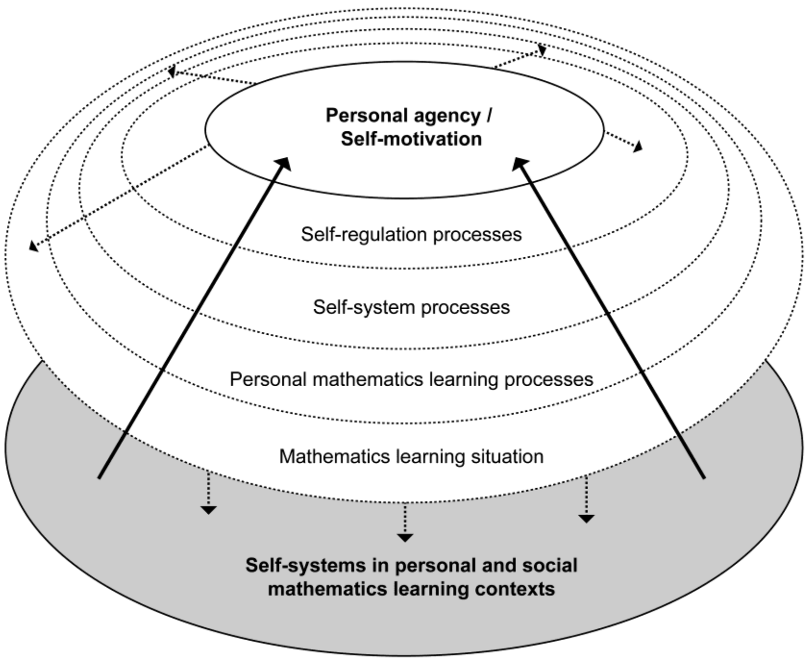



*Figure 3 Relational model of the dynamics between affect, cognition and social environment in the regulation of the personal learning processes (Malmivuori, 2001, p. 296)*

Other models explored the differences between students’ use of learning strategies, suggesting that a lack in metacognitive knowledge would result in ineffective learning processes (Weinstein and Mayer, 1986; Weinstein *et al.*, 1988a; Weinstein *et al.*, 1988b). At the same time, the learning environment may evoke ineffective learning behaviour, for example if the teaching is tightly focussed on exam preparation and students learn they should rely on memorisation techniques. Such “conceptions of learning” (Marton *et al.*, 1993) and how they may be influenced by the dominant learning culture in the learning environment are discussed in more depth in section 2.4.2.

### 2.2.2 Social constructivism and situatedness of learning

The interplay between learner and environment is also in the focus of social constructivist concepts of learning. In contradiction to behaviourist cause and effect models (Skinner, 1954) learning is described as a complex process, driven by interactions between the individual, the task, and the social context. From a developmental point of view, knowledge is acquired by observing and imitating others and by getting feedback from them. Vygotsky used the metaphor “zone of proximal development” for the distance between children’s’ individual ability and the next step of development they are able to achieve if guided by a parent, a teacher, or a more skilful peer (= an expert). This guidance can be relaxed and replaced by “scaffolding”: the expert observes the child’s activities and only intervenes if needed (Vygotsky, 1978). This concept has been found highly viable to describe learning from a social constructivist point-of-view. Learners gradually move from depending on others’ guidance to receiving help when needed (scaffolds) to being an expert themselves (see also section 2.5.3).

The social environment has been found particularly relevant for understanding why not all learning processes are successful. Based on her research on the mathematical ability of “jpfs” (“just plain folks”), Lave (1988) suggested that, rather than cognitive skills, environments and relations between people in different contexts added to success or failure in the practice of arithmetic. Lave and Wenger (1991) proposed the concept of “Situated learning”, focussing on the importance of social interaction for all human activities, including learning. In rejecting both "generalizability and / or abstraction of 'knowledge'" (Lave and Wenger, 1991, p. 37) and the underlying distinction between theory and practice the authors claimed that "there is no activity that is not situated" (ibid., p. 33).

Learning environments that acknowledge the situatedness of learning thus often postulate authenticity and offer multiple perspectives on a problem (Fischer *et al.*, 2009). The use of cooperative learning platforms is promoted, with students exchanging information and discussing problems, thus becoming part of a "community of practice" (Wenger, 1998; Brown *et al.*, 1989).

Johri and Olds (2011) suggested that the domain of engineering, with its focus on the applicability of (mathematics) knowledge and the (increasing) importance of collaborative work for the engineering workplace was highly suitable for the implementation of such learning environments. At the same time, many authors claim that engineering education is characterised by traditional teaching styles, exclusively focused on lecturing (Gill and O'Donoghue, 2008; Booth, 2008; Litzinger *et al.*, 2011; Ferrare and Hora, 2014).

### 2.2.3 Experiential learning and learning styles

Calls for a broader variance in teaching styles have particularly been made by authors that emphasise differences in students' learning styles. Based on experiential learning theory, Kolb identified four different styles. According to Kolb (1984), learning processes are characterised by the dialectics of action / reflection and experience / abstraction. In order to result into learning, concrete experience needs to be "grasped", or conceptualised. Accordingly, reflection on observations may induce active experimentation (and vice versa), thus "transforming" experience. His experiential learning cycle describes four adaptive learning modes, from concrete experiences (CE), reflective observations (RO), abstract conceptualisations (AC), to active experimentations (AE), and the interactions between them (Kolb, 1984; Kolb and Kolb, 2009).

Kolb suggested that the four elements of the learning cycle represented four different learning styles and that students with different preferences would benefit from different forms of instructions:

(1) Diverging (concrete, reflective)

(2) Assimilating (abstract, reflective)

(3) Converging (abstract, active)

(4) Accommodating (concrete, active)

According to this model, type (1) students, for example, respond well to explanations how the learning material relates to their experiences and interests. Type (2) learners, by comparison, prefer organised, well-structured presentation of information and also have been found to prefer lectures over other forms of teaching. They prefer to study individually and are less interested in practical activities. Type (3) students, as well, prefer abstract conceptualisation but are more likely to enjoy solving problems over listening to lectures and talks (Kolb and Kolb, 2009).

Alternative approaches to modelling learning styles have been suggested by Honey and Mumford (1992), who differentiated between (1) activists, (2) reflectors, (3) theorists, and (4) pragmatists, or Felder and Silverman (1988), who put a stronger focus on the sensual experience of learning: their five different learning styles ranged from (1) sensing, to (2) visual, (3) inductive, (4) active, and (5) sequential learners. Finally, Fleming and Mills (1992) distinguished between different forms of representation, from (V) visual and (A) aural to (R) reading and writing to (K) kinaesthetic knowledge presentation.

The different concepts share the presumption that learning styles are relatively stable individual preferences and that learners who are taught in their preferred style will benefit more from instruction. In that, the idea of learning styles differs from models of learning that suggest an interaction between students' conceptions and the environment (Vermunt, 1996). At the same time, the environment plays an important role as learners who are *not* taught in their preferred style might be disadvantaged.

As suggested by Kolb, engineering and mathematics students were more likely to be type (2) assimilators and type (3) convergers (Bernold *et al.*, 2000; Sharp, 2002). Both groups score high on the abstract-concrete scale but mathematics students have a slightly higher preference for reflection than engineers (Orhun, 2013). It thus can be presumed that many engineering students feel comfortable in the “typical” engineering environment with its focus on lecturing, but certainly not all of them (Kolb and Kolb, 2005). Kolb, as well as Felder, therefore suggested to expand the teaching styles in the engineering domain by more often switching between different modes of teaching and using different forms of representation, and by adding group discussions and collaborative projects to the curriculum (Felder and Silverman, 1988).

Criticism on the concept of learning styles has been raised because of the lack of coherence between competing models and conceptualisations (Coffield *et al.*, 2004). It also has been found difficult to differentiate between learners’ preferences, the way they perceive the learning environment, and their academic performance in this environment (van Zwanenberg *et al.*, 2000; Roberts and Newton, 2001; Reiss *et al.*, 2011).

Advocates of the learning styles concept claimed that the different item batteries were mainly designed to help learners reflect upon how they learned and to give teachers and lecturers an overview of the dominant learning styles in their course. Kablan (2016), for example, could show that a more active teaching style, employing mathematical experiments and group work, led to better performance of accommodators and divergers.

It can be summarised that employing a variety of teaching styles is certainly helpful for all learners, as they acquire metacognitive knowledge about how to learn most effectively (see section 2.3.1) and how to adapt to different learning environments (Felder and Brent, 2005).

### 2.2.4 Conclusion

In this chapter the guiding framework of self-regulated learning and its viability with other theoretical concepts was introduced. In its acknowledgement of the interplay between individual learners, their learning behaviour, and the learning environment, self-regulated learning relates to social constructivist models of learning that emphasise the situatedness of learning and students' goal to participate in a "community of practice" (Wenger, 1998). Active participation and interaction with the learning environment affect learners' self-reflection; an underlying concept that is in alignment with Kolb's experiential learning theory and will be addressed in section 2.4 on the use of learning strategies.

In its demand for authenticity and collaboration, social constructivism also relates to claims for "active teaching" and to "teach around the cycle" (Felder and Brent, 2005, p. 60). How to transfer the demand for authentic learning environments to the case of the web-based pre-course will be discussed in more detail in section 2.5.4.

The following chapters are structured alongside the triadic system learner (person, self), learning behaviour (use of learning strategies), and learning environment. As learning environment is the only element in this system that can be manipulated it is in the focus of the literature review.

| | Self-regulation dimension | Variables / operationalisation |
|---|---|---|
| The learner (person \| self) | cognitive | prior domain knowledge |
| | metacognitive | metacognitive prior knowledge (how to use learning strategies) |
| | affective | attitude, interest, motivation |
| Learning behaviour | use of learning strategies | self-monitoring, organisational strategies, practice, self-evaluation |
| | effort | learning activities, time on task |
| | approaches to learning | deep and surface |
| The learning environment (design) | (e)-learning environment | external monitoring, guidance, support, peers |
| | social environment | teachers, tutors, peers |

*Table 1 Different factors related to the framework of self-regulated learning*

## 2.3 The learner (person | self)

### 2.3.1 Cognition and metacognition

As shown in section 2.1.2, cognitive variables in general, and prior knowledge in mathematics in particular, are dominant predictors of tertiary achievement. Multi-dimensional models of tertiary performance suggest that students with broad domain-specific prior knowledge level also show high levels of self-regulation (Richardson *et al.*, 2012; Ackerman *et al.*, 2013). Self-regulated learning involves activities like planning, structuring, and self-evaluation. Learners have to decide when, in which environment, how long and how often they are going to learn. If the knowledge area is rather broad they may need to prioritise and in order to keep track of what has already been achieved and what is still to be done they have to constantly monitor their progress (Herzig, 2007). Pressley *et al.* (1989) described this metacognitive ability as “good information processing”. GIPs (good information processors) are learners who are able to activate adequate strategies when confronted with a task. They make connections between their subject-related prior knowledge and new information and they have the metacognitive knowledge to close the gap between both.

This meta knowledge, or knowing “how to learn”, is closely connected to the domain knowledge a student has acquired. Students who feel familiar within a domain, its language and its dominant teaching and learning techniques will find it much easier to add new information to the existing knowledge base than novices. Accordingly, metacognitive skills were added to the revision of Bloom’s taxonomy of learning (Anderson and Krathwohl, 2001).

Pintrich (2002) identified three different types of metacognitive knowledge:

(1) Strategic knowledge refers to knowing about certain strategies, how to memorise, how to summarise texts, how to structure the learning environment. These could be grouped into the three sub-categories rehearsal, elaboration, and organisation (Weinstein and Mayer, 1986).

(2) Knowledge about cognitive tasks is a conditional knowledge, knowing when to best employ which strategy. Certainly not all strategies are appropriate for all situations and learners have to decide when to use which. This metacognitive knowledge therefore refers to knowing what strategy is the most effective for performing well in a particular exam.

(3) Self-knowledge refers to learners' awareness regarding their own strengths and weaknesses (Flavell, 1979). This includes identifying one's lack of knowledge and finding adequate approaches to close these gaps (Pintrich, 2002, p. 221).

Metacognition therefore refers to knowing about the use of learning strategies, but also to applying them effectively. Just like domain knowledge, metacognitive knowledge and skills are likely to increase with each learning experience, which is why both types of knowledge are so closely connected. Students' metacognitive development also enables them to move from surface approaches to learning, like rehearsal and memorisation, to deeper approaches that are focused on understanding (Flavell, 1979; Biggs and Moore, 1993; Pintrich, 2002).

Attempts to teach metacognitive knowledge have been found more successful if embedded into the course curriculum (Hattie *et al.*, 1996; Simpson *et al.*, 1997; DeCorte and Masui, 2009) but such programmes need time to have a lasting effect (Zimmerman *et al.*, 2011). Teaching metaknowledge generates additional workload for students who already lack domain knowledge and thus may overburden inexperienced learners.

Cognitive load theory (CLT) postulates that working memory capacity is limited and that learning environments delivering too much information, thus “overcharging” working memory capacity, fail to support learning (Sweller *et al.*, 1998; Sweller, 2005). Sweller suggested distinguishing different forms of cognitive load, intrinsic, extraneous, and germane. Intrinsic load is related to the complexity of the cognitive task for an individual learner and thus a fixed parameter, depending on a learner’s prior knowledge level. Germane load refers to constructive activities of the learner, for example using self-explanations to better understand a mathematical concept (Renkl and Atkinson, 2003, p. 17). By comparison, extraneous load is caused by cognitive activities that are not directly connected to the learning process, e.g. searching for help, or navigating the website. This load can be reduced by a well-designed learning environment and the released memory capacity be used to engage in the learning process.

Students’ cognitive capacities may also be influenced by affective variables (Malmivuori, 2001), an interaction that will be described in the following section.

### 2.3.2 Affective factors and attitudes

Affective factors are attributed to the self, for example an individual’s liking of or interest in a subject. It is expected that students who are interested in a topic will feel a stronger motivation to spend time and effort for knowledge acquisition in this domain (Ryan and Deci, 2000). Thus a high level of interest is usually related to a high level of intrinsic motivation and both are considered to positively influence success on cognitive tasks.

*Interest and motivation*

Interest in a subject can be a motivational orientation, thus trait-like and stable. Individual interest develops over time and “represents a relatively enduring predisposition to engage in a certain object area of interest” (Krapp and Prenzel, 2011, p. 34). Situational interest, by comparison, is stimulated from the outside. It thus can fade rather quickly, or become the basis for an emerging individual interest. Individual interest may be fostered, or subdued, by a high or low degree of situational interest, thus both forms of interest interact and influence each other (Krapp and Prenzel, 2011).

Similar interactions have been suggested for motivational dispositions. While intrinsic motivation is an “inherent propensity” it is not independent of the learning experience and thus can be increased by external factors but may also be “disrupted by an unsupportive learning environment” (Ryan and Deci, 2000, p. 70). Thus intrinsic motivation may change with a person’s actual disposition, and may, indirectly, be influenced by the learning environment.

Competitive learning environments, for example, are more likely to induce performance orientations in students, so that even intrinsically motivated students develop a strong interest in marks and grades. Dweck (1986) distinguished between students’ orientation toward external or internal rewards. Students who are strongly concerned about marks and grades pursue “performance goals” and learning environments that are perceived as judging will make them choose tasks that provide with “opportunities to look smart” (Dweck, 1986, p. 1042). At the same time, such environments may demotivate students with low attainment (Black *et al.*, 2003) and may result in a negative attitude towards the subject.

*Attitude towards mathematics*

Attitude towards mathematics is a well-researched field and considered highly relevant regarding students’ motivation and persistence in the face of setbacks and frustration (Cretchley, 2008; Chamberlin, 2010). Attitude is closely related to interest in a subject, and some authors have treated both as similar concepts (e.g. Schreiner and Sjøberg, 2004) or modelled interest as a sub-category of attitude (Osborne *et al.*, 2003). As it is possible to dislike an issue and at the same time be interested in it (e.g. environmental pollution or the greenhouse effect) it might be reasonable to draw a distinction (Krapp and Prenzel, 2011, p. 31). Furthermore, attitude differs from interest as it can be positive or negative, and in each direction be influential for the learning process.

In school contexts attitude towards mathematics has been investigated in large international surveys, like the “Programme for International Student Assessment

PISA" (Baumert *et al.*, 2000; Artelt *et al.*, 2003; Prenzel and Baumert, 2008) or the "Trends in International Mathematics and Science Study TIMSS" (Kadijevich, 2006). The TIMSS study in particular focuses on students' knowledge in mathematics and science, and repeatedly revealed strong relations between attitude towards mathematics and test results. In this study, attitude was modelled based on three dimensions, (1) liking mathematics, (2) self-confidence in learning mathematics, and (3) value mathematics (Kadijevich, 2006; Mullis *et al.*, 2009) (for details, see chapter 2.6). For the TIMMS results of 2011, Mullis *et al.* reported strong correlations between attitude towards and achievement in mathematics for both examined cohorts, students from fourth and eighth grade. They also found that in eighth grade only 25% of the students had a positive attitude towards mathematics, and only 14% expressed confidence in their mathematics ability, indicating that during students' school careers both attitude and confidence considerably decreased (Mullis *et al.*, 2012, p. 20).

Students that have an outright dislike of mathematics will probably not enrol in an engineering course; at the same time the literature suggests that engineering students often struggle with mathematics at university and do dislike the subject.

Shaw and Shaw (1997; 1999), for example, conducted a series of studies on engineering students' attitudes towards mathematics. Based on a cluster analysis the authors categorised the students in different groups, from "High Flyers" who enjoy mathematics to "Haters" who are neither motivated to learn mathematics nor expecting to succeed. These two extreme groups, though, were rather small (+/- 10% each) whereas the larger clusters were much more heterogeneous. They were described as "Ambivalents" (35%) and "Downhillers" (~ 30%) who had lost their initially positive attitude towards the subject at university.

The first year experience may play a dominant role in such developments (see also section 2.1.4). Meyer and Eley (1999) hypothesised that particularly students who had liked mathematics at secondary school might be demotivated by the more abstract mathematics learning experience at university. Accordingly, an initially over-positive attitude might drop throughout the first year and approximate the attitudes of the general student body. Berkaliev and Kloosterman (2009) used an inventory previously administered at remedial college courses for university students in engineering and elementary education (Kloosterman and Stage, 1992; Stage and Kloosterman, 1995). The outcomes revealed no significant differences between groups in terms of mathematics liking or value; correlations between the different subscales were quite similar. The only, yet small, difference was that engineering students appeared to be more self-confident about their ability to learn mathematics.

Parsons (2014), as well, observed that engineering students' self-confidence in mathematics was higher when compared to natural science and social science students' confidence in statistics. In her thesis she analysed the role of confidence for predicting first and second year achievement. While the most dominant predictor was prior performance (GCSE scores), self-confidence also significantly contributed in a linear regression.

Finally, Besterfield-Sacre *et al.* (1997) observed that engineering students' performance and self-beliefs not always correlate. In a study analysing first year engineering students' reasons to withdraw from their course the authors found that in the group of leavers poor performing students were less concerned or doubtful regarding their own abilities and/or preparedness than those with relatively good performance. The authors hypothesised that the latter tended to lack self-confidence while "at risk" students were more likely to be over-optimistic. Similar conclusions were drawn by Zimmerman *et al.* (2011) who suggested that engineering "at risk" students more often tended to overestimate their own abilities (Bol and Hacker, 2001) and thus needed a learning environment that evoked a constructive but realistic self-reflection.

### 2.3.3 Conclusion

It was shown that next to existing cognitive and metacognitive skills and knowledge, students' preferences and experiences are relevant for describing the "self" in the self-regulation process. Students who are interested in a subject are more likely to engage in learning activities and thus show a better performance (Krapp and Prenzel, 2011). Good grades will have a motivating function and make it easier to put effort into the learning process even when it is sometimes difficult or laborious (Ryan and Deci, 2000). On the other hand a poor performance can negatively affect students' attitudes towards a subject (Black *et al.*, 2003). Thus person-related variables, from prior knowledge to interest and attitudes are positively correlated with students' ability to self-regulate.

Traditional cognitive variables usually outperform non-traditional scales in predicting tertiary performance (Parsons *et al.*, 2009; Richardson *et al.*, 2012; Ackerman *et al.*, 2013), but affective variables and variables related to the use of learning strategies often add informational value (Robbins *et al.*, 2004) and thus should be included in predictor models.

## 2.4 Learning behaviour

Zimmerman and Moylan (2009) provided a social-cognitive perspective on self-regulation that stressed the interactive and cyclical nature of learning. They suggested to relate the different person-related and environmental variables to three phases, (1) forethought and task analysis, (2) performance and self-control, and (3) self-reflection and self-judgement (see Figure 4). The forethought phase is related to the anticipation and preparation of action; learners activate existing domain and metaknowledge, set their learning goals in relation to this knowledge and decide what action is needed. The performance phase then demands the use of task strategies, like structuring of the workplace, time management, but also seeking help when faced with setbacks. How effectively students make use of these strategies during the performance phase is relevant for the outcomes of the learning process. The evaluation of the process then takes place in the self-reflection phase. Self-reflection includes anticipation and planning of subsequent learning activities, thus closing the cycle (Zimmerman *et al.*, 2011).

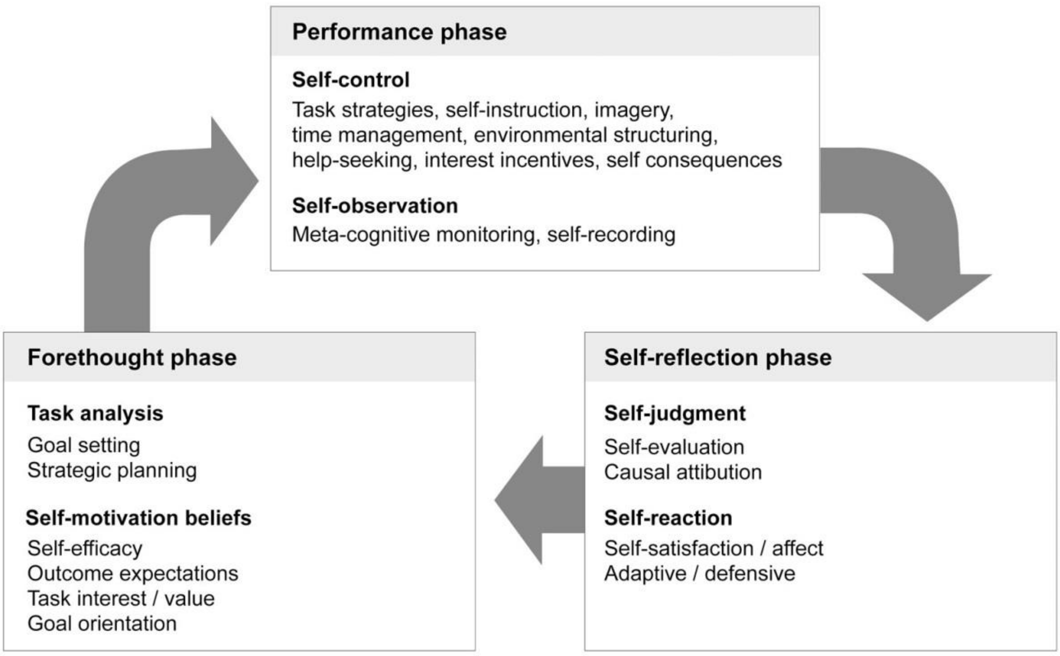



*Figure 4 Phases and processes of self-regulation as modelled by Zimmerman and Moylan (2009), p. 300*

According to Zimmerman and Moylan, task strategies are related to learners' activities during the performance phase, whereas other authors used learning strategies as an overarching construct. According to Weinstein and Mayer (1986), for example, learning strategies included metacognition and strategic knowledge ("skill") as well as motivational aspects ("will"). Pintrich (1999), by comparison, differentiated between cognitive learning strategies, metacognitive and regulation strategies, and resource management strategies. DeCorte *et al.* (2000) suggested that using appropriate learning strategies was a mathematical ability in its own right.

It is, however, generally agreed upon that the use of metacognitive strategies, from planning the learning process to providing an adequate learning environment to self-monitoring and self-evaluation, is central to the concept of self-regulated learning. In this review, learning strategies are understood as metacognitive activities linked to self-control during the performance phase as defined by Zimmerman and Moylan (2009). It is differentiated between *organisational and time management strategies, task strategies,* and *help seeking.* Considering the high workload in engineering courses, time on task will also be included in this review.

### 2.4.1 Use of learning strategies

Large scale assessments of students' use of learning strategies have a relatively long tradition in North-American educational research. The "Motivated Strategies for Learning Questionnaire MSLQ", developed by Pintrich *et al.* (1991), for example, has been used in numerous studies investigating the influence of metacognitive variables on tertiary performance.

*Organisational and time management strategies*

One fundamental part of the performance phase is to provide an adequate learning environment (a quiet room, no distractions, sufficient time to study) and to plan when to study and what to achieve. It has repeatedly been shown that the use of time management and organisational strategies is positively correlated with achievement (Credé and Phillips, 2011; Richardson *et al.*, 2012).

Martin (2012), for example, investigated non-traditional students' use of learning strategies. For his thesis he compared a group of students who had already dropped out of a previous course programme with a group of students who had successfully completed a degree. He found that successful students made significantly more use of learning strategies like time management, optimisation of the learning environment, or seeking for additional information.

Barnard-Brak *et al.* (2010) developed different profiles of self-regulated learners and related them to academic achievement. They found that students with "disorganized profiles" were also more likely to show poor academic performance. Thus high performing students are more likely to be effective in their learning (Weinstein *et al.*, 1988b; Macan *et al.*, 1990; Britton and Tesser, 1991; Entwistle and McCune, 2004; Plant *et al.*, 2005). Compared to other strategies, time management and organisational strategies have been found very consistent predictors of performance (Broadbent and Poon, 2015).

*Time on task*

Study time, or time on task, has been found very difficult to quantify. Kember (2004) showed that actual time spent learning and perceived workload were only weakly correlated, suggesting that either students failed to accurately remember the time they spent learning or that they had diverse perceptions of what a "high" workload was in relation to the learning task. Thus a true objective workload is impossible to measure and much research refers to the question of how to build adequate models of student workload (Karjalainen, 2006; Baeten *et al.*, 2010; Bowyer, 2012).

At the same time it has been found relevant to include study time for the group of "at risk" students. Students with poor prior knowledge are more likely to procrastinate (Helmke and Schrader, 2000; Michinov *et al.*, 2011) and not having enough time to reach their learning goals. In a study on undergraduates' use of learning strategies in e-learning environments Artino and Stephens (2009) found that poor performers showed a much greater tendency to procrastinate. It also has been found that students' perceptions of the workload and their actual study time often differ. Kolari *et al.* (2008), for example, provided evidence that, compared to the workload suggested by the curriculum, engineering students spent only 63% of the allocated time for learning.

Study time, albeit being a relatively unreliable predictor of academic success, may provide meaningful information if related to prior performance. Plant *et al.* (2005) investigated why study time was a weak predictor of study success. In a study with first year students from different domains (psychology, education, sports) they performed a hierarchical regression including answers to a questionnaire on learning routines, logs from a weeklong learning diary, and college GPA. They also added high school GPA and scores obtained from the SAT. Not surprisingly, prior performance had a strong influence on college GPA, but after controlling for these variables they found significant effects for a quiet study environment, an organised approach to learning, and regularly attending classes. In their model, study time thus only emerged as significant in combination with prior performance.

Kember *et al.* (1996) analysed how time on task, measured by a learning diary, affected mechanical engineering students' GPA. They found a positive correlation between study time and achievement, but they also observed that many students who invested an overproportional amount of time into learning performed quite poorly. The authors suggested that these students used mainly surface approaches to learning and thus used their time ineffectively (see section 2.4.2).

*Task strategies*

Task strategies refer to basic learning activities like reading, searching for additional information, or rehearsal. While all students make use of such strategies, not all may do so in an efficient way; their relevance for the outcomes of the learning process is thus difficult to quantify. Accordingly, the literature is inconsistent regarding their impact on achievement. A meta-study carried out by Credé and Phillips revealed that subscales related to "rehearsal", "elaboration", or "peer learning" were largely unrelated to academic performance (Credé and Phillips, 2011).

These studies are in contrast to research by Macfadyen and Dawson (2010), who found rehearsal to be a good predictor of performance in an online biology course.

Chang (2007) and ChanLin (2012) reported similar relations for tertiary e-learning courses in English and media services.

For the domain of mathematics the role of rehearsal may have an even higher relevance. It could be shown that web-based training of basic skills was particularly helpful for students who struggled with the learning contents and needed to catch up with the rest of the class (Koedinger and Corbett, 2006; Genlott and Grönlund, 2016; Witte *et al.*, 2015; Pachman *et al.*, 2013).

One reason for the overall inconsistent role of rehearsal is the difficulty to differentiate between "mindless repetition" (Weinstein *et al.*, 2011, p. 47) and "goal orientation" as suggested in the theoretical framework of deliberate practice (Ericsson *et al.*, 1993). If learners consciously make use of a rehearsal regime that aims at consolidation of skills even repetitive learning activities can be "mindful" and based on self-reflection.

*Help seeking*

Help seeking refers to a learner's ability to activate social resources. Students who ask peers or turn to their tutors and lecturers for help need to reveal that they do not know the answer to a problem. Often high performing students are more able and willing to do so, whereas students with a low knowledge level may be reluctant to show their need or find it difficult to formulate a question (Karabenick and Knapp, 1988; Newman, 2002; Karabenick, 2004). As suggested by Zimmerman (2002), it indicates a high level of self-regulation if learners seek out help from others to improve their learning.

Such relations also apply to learning in groups and to discussing mathematics problems with peers. Mazur (1997), for example, showed the effects of peer instruction on students' ability to understand mathematical problems. At the same time, students with poor domain knowledge might need to learn how to benefit from such discussions. Dancer *et al.* (2015), for example, showed that peer-assisted study sessions in statistics significantly improved poor performing students' grades, provided that they had been introduced to effective ways of group learning.

Considering such interactions, measuring the effects of help seeking on learning outcomes often results in contradicting outcomes. For e-learning environments, Barnard *et al.* (2009) found significant results for environmental structuring, task strategies, time management, help seeking, and self-evaluation. A recent meta study on the use of learning strategies in e-learning, however, found no effects for help seeking or peer learning, whereas time management as well as elaboration and rehearsal significantly predicted academic achievement (Broadbent, 2017).

Zimmerman *et al.* (2011) suggested that “at risk” students needed to learn how to reflect their learning outcomes and to put them into perspective. They conducted an intervention study to foster engineering students’ self-regulation ability with a focus on self-assessment and self-reflection. An experimental group of “at risk” technical college students received instruction on self-regulation strategies in their mathematics course; a similar control group had no such training. The experimental group outperformed the control group in a set of mathematics examinations and had a higher pass rate on final exams.

It thus can be summarised that students with poor domain knowledge are less likely to plan, structure, carry out and reflect their learning. The following section provides an explanatory model why students differ in their conceptions of and their approaches to learning.

### 2.4.2 Approaches to learning

Marton and Säljö provided a framework that accounted for the differences between effective and ineffective learning activities. In their initial study students had been asked to read and summarise a text and the authors wondered why some of the students had "totally missed the point" in this relatively easy task (Marton and Säljö, 1976; Marton and Säljö, 2005). In a phenomenographic approach they explored differences between students' approaches to this task and identified two main categories (Marton and Säljö, 1976; Marton and Säljö, 2005). Students who gave an adequate summary of the article had focused on its content and had expressed the intention to understand it, which was referred to as a *deep* approach. By contrast, students following a *surface* approach had been focused on remembering and reproducing the text as accurately as possible, without giving thought to its key messages. Marton and Säljö suggested that particularly inexperienced learners tended to use such approaches and that, by experiencing a learning environment that fostered understanding, they would progress to deeper approaches.

This fundamental concept was found highly viable for the educational research discourse. Biggs (1978), for example, had observed similar learner behaviour in his studies and adopted the term "approaches to learning". In his "3P" model of teaching and learning he described the interaction between presage (students' preconditions and the learning environment), process (the learning activities), and product (learning outcomes). According to this model, students have their own motives and approaches to learning, but are also influenced by the environment. Therefore, in addition to deep and surface approaches, Biggs (1987b) introduced a third dimension, the achieving approach (Biggs, 1987b, p. 10). This approach was considered to be extrinsically motivated, for example when students were mainly interested in obtaining high grades, regardless of subject or learning content. A competitive environment was likely to foster such an approach, therefore the inventories addressed external influences, as well.

During the last decades a large body of work further developed the concept qualitatively and quantitatively. Similar to Biggs, Entwistle *et al.* (1979) identified a third approach, referred to as “strategic”. The authors also suggested a fourth approach, called “non-academic”, combining negative and “pathologic” attitudes to studying, expressed in ineffective and improvident learner behaviour (Pask, 1976). In a large-scale study using a set of scales (“Approaches to Studying Inventory ASI”) it was shown that students’ approaches to studying were strongly influenced by their conceptions of the learning environment, and how they perceived the nature of their course (Entwistle and Ramsden, 1983).

*Approaches to learning mathematics*

The original work of Marton and Säljö was also developed further regarding learning in different disciplines. For the domain of science and mathematics, Laurillard (1979) used interview and questionnaire data to explore students’ thoughts and strategies when solving a problem. The outcomes of these analyses showed similarities to students’ approaches to the reading task. Some showed an interest to understand the problem and to relate it to their own knowledge, an intention referred to as “meaningful” learning. Other students used a much more superficial way of learning, described as “more passive, with the student content to treat the elements of the task in a purely mechanical way, not considering their meaning, merely their form.” (Laurillard, 2005, p. 134). The author also observed that, depending on the occasion, students used both approaches, supporting the view that students’ interpretation of what was expected from them strongly influenced the solving process. If a problem could easily be solved using a “standard procedure” students would do so, and, as the author pointed out, why shouldn’t they? She suggested that some learning situations could be identified where surface approaches were perfectly viable.

Crawford *et al.* (1994) described surface approaches to doing mathematics as reproduction-oriented and characterised by “rote memorization” whereas a deep approach to learning and to understanding mathematics was related to “doing difficult problems” and “applying the theory” (Crawford *et al.*, 1994, p. 343). The authors contrasted students’ (structural) approaches to learning with their (referential) conceptions of mathematics. They hypothesised that students' approaches to learning were strongly influenced by their general concept about mathematics, from a fragmented conception - mathematics as "rules, numbers, and formulae" - to a cohesive one - mathematics as a "complex logical system which can be used to solve complex problems and provides new insights used for understanding the world" (Crawford *et al.*, 1994, p. 335). Together with a modified version of Biggs's "Study Process Questionnaire" their own "Conceptions of Mathematics Questionnaire" was administered to science and engineering students (Crawford *et al.*, 1998a). They found that students with a fragmented conception of mathematics were more likely to use approaches to learning that were related to reproduction. Accordingly, high scores on the cohesive conceptions scale could be related to high scores on the deep approaches to study scale (Crawford *et al.*, 1998b, p. 93).

| | Intention (referential) | |
|---|---|---|
| Strategy (structural) | Reproduction | Understanding |
| Rote memorisation | A | |
| Doing lots of examples | B | C |
| Doing difficult problems | | D |
| Applying the theory | | E |

*Table 2 Relationships between the referential and structural aspects of students' approaches (from Crawford et al., 1994, Table 4, p. 338)*

They also observed that students who felt overburdened by the workload were more likely to use surface approaches to learning, supporting previous research that the learning environment plays an important role in this model. Students who held cohesive conceptions of mathematics also appeared to perceive the environment as satisfactory and showed a higher performance in mathematics (Crawford *et al.*, 1998a). The authors suggested that lecturers should be more aware of these relations and of how teaching styles might influence students' conceptions.

*Mathematics learning strategies of engineering students*

As discussed earlier the environment may significantly influence how students learn and what strategies they use. With reference to such interactions it has been discussed how the environment “engineering education” may determine students’ approaches to learning. It has been hypothesised, for example, that a traditional teaching style, characterised by little interaction between lecturer and students, many (multiple choice) assignments and a generally high workload fosters surface approaches. Based on such considerations, Entwistle and Tait (1990) analysed first year electrical engineering and psychology students’ scores on a modified version of the ASI (“Approaches to Studying Inventory”). They could show that students who adopted a surface approach also preferred a learning environment that facilitated rote learning. By comparison, students with a deep approach showed a preference for active learning environments that promote understanding. It also could be concluded from this study that a high workload can foster rote learning and surface approaches, particularly in students with a high achievement orientation. However, the relations were not distinct enough to claim that the environment would *cause* a certain approach.

Approaches to learning thus are influenced by the environment, but also by students’ previous learning experiences and personal preferences (Kolb and Kolb, 2005). It is evident that, depending on the context, learners change their approach. Furthermore, inexperienced learners more often make use of memorisation and reproduction strategies, whereas advanced students are more likely to follow a deep approach.

Richardson *et al.* (1999), for example, found that distance learners more often showed desirable approaches to studying than on-campus students and could ascribe these differences to students’ level of learning experience. Their large-scale study with Open University students also revealed correlations between scores in the approaches to study inventory and performance.

Tynjälä *et al.* (2005) analysed these relations for the engineering domain. In their study 394 completed surveys, based on Entwistle and Ramsden’s ASI and Vermunt and Van Rijswijk’s ILS and own work, were related to students’ credits and tertiary

GPA. There were significant correlations between performance measures and students' approaches to learning, suggesting that a deep strategy was a predictor of study success. The study also revealed that poor performing students more often seemed to expect their lecturers to help them structure their learning and provide them with (reproductive) learning tasks.

Gynnild and Myrhaug (2012) reported similar results from a qualitative study carried out in a course in oceanography. Their results indicated that poor performing students more often were dissatisfied with non-traditional forms of teaching and assessment. The authors also observed clear relations between performance and students' level of self-regulation, their approaches to learning (from surface to deep) and their self-confidence.

It thus seems that students sometimes fail to appreciate or benefit from a learning environment that was designed to be activating, or fostering a deep approach. Particularly when feeling under pressure (by the workload, an unfamiliar environment, and fear of an exam) learners tend to fall back to well-known and basic approaches.

Case and Marshall (2004) provided an approach that helped to better understand such a behaviour in the context of engineering. Based on the outcomes of their theses the authors suggested to further differentiate between approaches to studying. Marshall (1995) conducted a phenomenographic study with 13 participants of a foundation course in the UK; Case (2000) did a comparable study with 11 second-year chemistry students in South Africa. Both authors identified a surface approach that, against the assumptions made in previous research, appeared to result in deeper understanding. Students reported that exercising and doing a lot of problems helped them to become familiar with and finally understand complex mathematical concepts. In a joint report it was suggested that engineering students' approaches to learning were determined by their intentions (passing the test or understanding) and their strategy use (memorisation, problem-solving, or conceptual). They repeatedly observed that students would follow a *procedural surface approach* for some time before eventually changing to a *procedural deep approach*, no longer related to exam scores but to understanding. The authors thus hypothesised that there perhaps was “some sense in the advice often given to science and engineering students to practise lots of problems, and that understanding will come in the long run?” (Case and Marshall, 2004, p. 612).

| | Intention | |
|---|---|---|
| **Strategy** | Passing the test | Understanding |
| Memorisation | Surface Approach | |
| Problem-solving | Procedural surface approach | Procedural deep approach |
| Concepts | | Conceptual deep approach |

*Table 3 Approaches to learning in the field of engineering (Case and Marshall, 2004, p. 613)*

These observations were in line with the “paradox of the Chinese learner” (Marton *et al.*, 2005b; Marton *et al.*, 1996), referring to the counter-intuitive observation that memorisation and repetition, which are fundamental to learning and teaching in Asia, obviously do result in deep understanding.

Eley and Meyer (2004) suggested that surface approaches in mathematics not necessarily indicate a general orientation towards rote learning. Memorisation or preferring simple problems might represent an “early ‘way station’ along the transition from ‘doing nothing’ through to an eventual complementing combination of ‘deep’ processes.” (Eley and Meyer, 2004, p. 449).

At the same time, the development from a rote memoriser to a deep conceptualiser will not happen automatically, and if the learning environment does not support this transition it may not happen at all (Case and Marshall, 2004). As stated by Laurillard:

> “Students take a largely rational approach to learning. They consider what is required of them, they decide on priorities, and they act accordingly.” (Laurillard, 2005, p. 144).

### 2.4.3 Conclusion

How and how often students make use of learning strategies can be an indicator of the “quality” of the performance phase and their overall ability to self-regulate. While the literature is quite consistent regarding the relevance of time management and organisational strategies for successful learning processes there are often contradicting results for the role of task strategies. Measures like time on task or the numbers of exercises may indicate a high level of effort as well as an inefficient surface approach to learning.

Interactions between the environment and students’ approaches to learning have been suggested for the domain of engineering and need to be considered when evaluating learning behaviour in the pre-course in mathematics. It also has been found that even a “rote” and superficial approach to learning may result in deeper understanding, provided that at some point in time students start to reflect upon the relevance of basic strategies and to make connections between them.

## 2.5 The learning environment (design)

This section focuses the role of the (e)-learning environment and how learning processes can be affected by changing its design.

### 2.5.1 E-learning

In this chapter the field of e-learning research is introduced by a definition of e-learning and other expressions used in this thesis, followed by a discussion of the major assumptions related to technology-based learning and its advantages and disadvantages. Research on the differences between face-to-face and technology-based learning is discussed in the section on comparative research.

#### *2.5.1.1 E-learning definition*

The moving field of e-learning has been described in various definitions, initially focussing on technical aspects. In 2001, the European Centre for the Development of Vocational Training CEDEFOP described e-learning as

> "learning that is supported by information and communication technologies (ICT). E-learning is, therefore, not limited to 'digital literacy' (the acquisition of IT competence) but may encompass multiple formats and hybrid methodologies, in particular, the use of software, Internet, CD-ROM, online learning or any other electronic or interactive media." (CEDEFOP, 2001, p. 5f.).

The definition implies that one prerequisite for e-learning is familiarity with the use of communication technologies. Learners without access to computers or the internet at home are not likely to develop this form of literacy, a disadvantage that has been referred to as the "digital divide". For today's secondary school graduates this issue might be disregarded as the use of computers and the internet has become a common element of their daily life. According to the "JIM Studie 2013", a long-term study on the media use of youths in Germany, 97% of the cohort of 12 to 19 year olds use the internet at home, and 88% have this access in their own room (MPFS, 2013, p. 27). According to Open University surveys on the media use of their students, access to computers and the internet was already common in 2002. Computer unfamiliarity appeared to be relevant for elder students in certain study domains only (e.g. health and social welfare) and did not apply for students interested in technical courses (Kirkwood and Price, 2005). The digital divide obviously no longer plays a role when addressing adolescents in European countries, consequently the 2010 “Digital Agenda for Europe DAE” describes the educational and social disadvantages connected with digital illiteracy as an important issue for the group of elderly citizens (Haché, 2011).

With the expansion of web-based technology and communication, the scope of e-learning has been extended and alternative expressions have been proposed, e.g. “Hypermedia Learning Environments (HLEs)” (Greene *et al.*, 2010), or “Technology Enhanced Learning Environments (TELEs)” (Kaleidoscope seed project, 2007).

As an addition to classroom instruction learning management systems (LMS) have become common at schools and universities. Today, LMS are integrated in most higher education institutions’ IT structure. For the United Kingdom, the distribution of these platforms has been analysed by the Joint Information Systems Committee (JISC) in 2008. They stated that nearly 90% of universities in the United Kingdom used the learning management systems Moodle or Blackboard. There is no similar survey for Germany, but the most commonly used LMSs appear to be the open source systems Moodle and ILIAS (Kerres *et al.*, 2009).

Virtual universities, like UK’s Open University, or Germany’s *Fernuniversität* Hagen, offer degree courses that are taught at a distance, and increasingly online. In the field of corporate training e-learning courses have become an established form of qualification, as well, addressed by terms like “Telematic learning”, “Distance Learning”, or “Distributed Teaching” (Grotlüschen, 2003). Following the “Web 2.0” paradigm, the communicative and interactive potential of e-learning has been represented by terms like “Computer-Supported Collaborative learning (CSCL)” (Carell, 2006).

In their review of research on distance education Tallent-Runnels *et al.* suggested to differentiate between (1) *Web-based education* for the general use of communication technologies and the internet for instructional purposes; (2) *Online classes* for courses that are taught via the internet; (3) *Hybrid or blended courses* for a combination of web-based and face-to-face instruction; and (4) *distance education* for "any courses that are delivered to students who are not present in the same room." (Tallent-Runnels *et al.*, 2006, p. 94).

In a 2012 study Sangrà *et al.* made the attempt to unify the existing definitions of e-learning, based on literature and a survey with 33 European e-learning experts. They finally agreed upon the following definition:

> "E-learning is an approach to teaching and learning, representing all or part of the educational model applied, that is based on the use of electronic media and devices as tools for improving access to training, communication and interaction and that facilitates the adoption of new ways of understanding and developing learning."
> (Sangrà *et al.*, 2012, p. 152)

Though certainly viable in the first part that covers most aspects related to e-learning, this definition postulates that the use of tools will lead to "new ways" of learning, an assumption that is contrary to the state of knowledge derived from comparative research and to the widespread use of various kinds of communication technologies. Hoffmeister (2005) even stated that e-learning was a "superfluous term" and could as well be abandoned. She claimed that elaborate e-learning programmes have been superseded by blended learning designs on the one hand, and informal ways of learning with Google, Wikipedia or online forums on the other (Hoffmeister, 2005, p. 288).

Considering the development in recent years, the term e-learning indeed appears to be a little out-dated. On the other hand, it has become a common expression in colloquial and scientific language and it is broad enough to adapt to the relatively fast changing technological trends in education.

> "Despite their seemingly diffuse nature, what all these products and resources have in common is that they involve electronically mediated learning in a digital format that is interactive but not necessarily remote."
> (Zemsky and Massy, 2004, p. 5).

For the remainder of this text, the following terminology is suggested:

- *E-learning* will be used to describe learning supported by the use of technological tools. Regarding the mathematics pre-course described in this thesis, e-learning is characterised by the following components:

- the course material is provided online, via an e-learning environment, in this case a learning management system (LMS).
- students and lecturers are physically separated
- the (major part of the) learning process is asynchronous

- *Blended learning* describes an e-learning design initiated, enhanced, or accompanied by face-to-face meetings between peers and lecturers. These meetings are strongly related to the e-learning environment and the self-study process, thus may be regarded as preparatory or follow-up meetings.

- If these class sessions last longer than the online sessions and are not directly related to the e-learning course material, the term *face-to-face course* will be used.

#### *2.5.1.2 E-learning and face-to-face learning*

Terms like multimedia learning, computer based training (CBT), Telematics Learning Environment (TELE), Virtual Learning Environment (VLE), Online Learning Environment (OLE) or Distance Education (DE) reflect the different facets of technology-enhanced learning and are representative for the stages of development, from video discs and learning programmes on CD-ROM to Computer-Supported Collaborative learning (CSCL), Massive open online courses (MOOCs), or Virtual University Degrees.

Research in the field of technology-enhanced learning was long focused on the difference between “conventional” methods like face-to-face or classroom learning (or learning with books) and the current cutting-edge technology. The goal of comparative research was mainly to prove (or question) the superiority of technology-supported methods. For example, the effects of the technical novelty “multimedia” were investigated, assuming learning to be easier and deeper with pictures, animations, sound and text presented on computer screens (Mayer, 2005). But the question whether learning from “new” or multiple media is more effective than from “old” media or forms of teaching could not be answered consistently. It appeared to be very difficult to isolate the influence of media from that of the underlying didactical concept (Clark and Craig, 1992). Though there is evidence that pictures, animations and sound can enhance cognitive processes (Mayer, 2003), the benefits of visual and / or auditory media for learning are not "exclusive to multimedia" and therefore can be "provided by human tutors", as well (Clark and Feldon, 2005, p. 100).

Mayer (2005) claimed that comparative research was often based on the overoptimistic assumption that technology could change the way people learn. Similar to the revolutionary effects once predicted for television, radio or cinema each e-learning innovation was accompanied by high hopes and promises (Cuban, 1986, and Casey, 2008, provide historical reviews for both multimedia and distance education). According to Mayer, research on multimedia-learning should investigate how learners can be assisted in the best possible way and stop the "no significant difference" debate (Clark and Salomon, 1986). With the increasing importance of the internet this debate shifted from multimedia to web-based learning, accompanied by comparative research on the differences between face-to-face and distance education. Bernard *et al.* conducted a review on 232 articles on distance education and their overall conclusion showed an "extremely wide variability in effect size on all measures" (Bernard *et al.*, 2004, p. 405), e.g. learning gains, learner satisfaction, or attitude. The authors summarised that a considerable number of distance education courses were found superior to face-to-face courses in terms of achievement, acceptance and persistence; and that the same could be said about a considerable number of face-to-face courses in comparison to their e-learning counterparts (Bernard *et al.*, 2004, p. 406). The authors attributed a greater part of this heterogeneity to a "lack of scientific rigor" in most of the reviewed studies; they also suggested that the idea of comparative research was misinterpreted by searching for significant differences. Both distance education and face-to-face instruction make use of media, or the internet, they are not media in themselves. A web-based course may offer recordings of a lecture and a face-to-face course may afford internet research. Therefore the principles leading to good e-learning or good classroom learning "should be, in principle, relatively equal to one another, regardless of the media used" (Bernard *et al.*, 2004, p. 382). According to the authors, the major differences between distance and classroom instruction can be reduced to (a) distance between learner and teacher and (b) asynchronicity.

Other meta-studies, as well, proclaimed a “no significant difference phenomenon” (Russell, 2001; Phipps and Merisotis, 1999) or at least stated that “comparisons of learning between different instructional modes, such as between online and traditional instruction, might be questionable” (Tallent-Runnels *et al.*, 2006, p. 106).

In summary, it can be stated that distance education and e-learning by now are common to primary, secondary and tertiary education. Universities use learning management systems to provide learning material online, students and staff use the world wide web and open learning resources as a knowledge base (e.g. Khan academy, www.khanacademy.org). With e-learning being one option to deliver learning contents, the main discussion has moved from “if” to “how” technology-enhanced learning can be successful.

#### *2.5.1.3 E-learning assumptions*

In this section three major assumptions related to the use of e-learning are introduced and discussed in relation to the study interest:

- Cost-saving assumption
- Time and place independency assumption
- Digital natives assumption

*Cost-saving assumption*

According to Clark and Feldon (2005), the only measurable advantages of e-learning, or distance education, are cost-savings for large institutions and easier access for people who do not have the chance to attend a face-to-face taught course. Travel expenses and loss of working hours indeed can be avoided when employees are trained online, thus the potential of learning technology to reduce costs has been of particular interest for large companies. The actual savings, though, have been found difficult to quantify, as costs highly depend on the topic, the complexity, and the intended outcomes of a training. For example, if the learning material is subject to periodic changes and all e-learning resources have to be revised on a yearly basis, the overall effectiveness might be poor. Furthermore, communication technology is constantly evolving and learning programmes can become out-dated or no longer interact with an organisation's technological infrastructure. Given the complexity of these issues "it is not only unrealistic to try to isolate the impact of an e-learning initiative but possibly very time-consuming and expensive" (Reddy, 2002, p. 31).

From a university's point of view cost saving arguments may be less relevant; the idea of a "notebook university" (Kerres, 2004) providing campus-wide internet access and a broad range of technically supported learning opportunities is certainly grounded in the demand to keep up with general social and technical developments. The implementation of learning management systems throughout tertiary education thus was an additive and did not cause a decrease of lectures or face-to-face seminars. Accordingly, the cost-effectiveness of learning managements systems, even of open source applications like Moodle or ILIAS, is questionable. It is very time consuming to produce didactically sound e-learning material and without extra funding for the development of course concepts and interactive resources many Moodle courses are constrained to the up- and download of scripts, an effect that inspired Kerres to refer to LMS as "data cemeteries" (Kerres, 2006, p. 5).

Throughout Europe, third party projects have been used to initiate e-learning in tertiary education, but many projects did not outlive the funding period. For his dissertation, Kreidl investigated into the reasons for implementing e-learning in higher education in Austria. From his interviews with e-learning staff and project managers from eleven universities he found that a majority of e-learning projects might never have been initiated were it not for government-funding (Kreidl, 2011).

To summarise, e-learning may help reduce costs when a certain number of participants are involved, but it has been found impossible to specify at which point e-learning becomes economically more interesting than face-to face learning. From a learner's (or employer's) point of view one main advantage is the reduction of travel costs, combined with the possibility to earn a living while studying. Therefore e-learning is an option when addressing the transition phase between secondary and tertiary education.

The participants of this study, prospective DHBW Manheim students, stemmed from different areas in Germany; travel and accommodation costs thus were likely to affect their choices. For the *optes* project, funding was secured for five years, plus a prolongation of four years. Assuming that the programme was used by several cohorts of approximately 600 students per year the target group of the project was large enough to justify the effort of developing an interactive learning environment. The learning curriculum in basic mathematical knowledge probably will remain (more or less) unchanged during the next decade, therefore it can be hoped that the web-based learning material will not consume additional resources after initial implementation (and one or two revisions).

One highly relevant resource-saving aspect is the automated feedback to self-assessments provided by e-learning environments. Marking is an extremely time-consuming activity; systems that relieve lecturers and tutors from this task are particularly helpful when it comes to practising simple problems (Jurecka, 2008).

*Time and place independency assumption*

> “One distinguishing characteristic of online learning is the autonomy students experience in the learning environment.” (Barnard *et al.*, 2009, p. 1)

The flexibility to learn wherever and whenever has been one of the strongest arguments pro e-learning. Family commitments or job-related obligations can be brought in line with the interest for personal qualification, therefore e-learning has been described as particularly attractive for adult learners.

Ridley *et al.* (1997) conducted a survey with students enrolled in the online version of a university’s full-time course. They wanted to know why students had decided to take the online course, and if the face-to-face version would have been an alternative. The results showed that distance and travel expenses were important reasons for taking online-courses and that many online students would not have chosen the traditional course, suggesting that the online version led to a higher number of enrolments. Unexpectedly, also students living near the campus often chose the e-learning version, some out of preference for new media or the hope to develop online skills, others because they wanted to be time-independent.

Independency, however, demands a proficient use of learning strategies. Kirkwood and Price (2005) evaluated quantitative and qualitative surveys that have been conducted at the Open University from 1996-2002, adding up to approx. 80,000 respondents. Most data stemmed from large-scale postal surveys in connection with Open University course evaluations. These data were used to collect information on students' media use, their access to the internet and their satisfaction with the ICT modules that were provided along with their course of study. The authors claimed that Open University students (80% study part time), valued independent learning and were initially capable to self-organise. Still, their strategies to plan and structure the learning process should be supported by adequate instructional designs. With growing variety in communication technology, students could be enabled to "locate, retrieve and interact with educational resources and engage with teachers and fellow students in ways not previously possible." (Kirkwood and Price, 2005, p. 258).

*Digital natives assumption*

In the "early years" of e-learning it was debated if technology use could increase students' motivation to learn, assuming that positive attitudes towards computers, or the internet, could be transferred to less popular activities, like learning. Schulmeister, for example, hypothesised that the novelty of computer based learning in itself could arouse enthusiasm because it was different from traditional forms of education (Schulmeister, 1996, p. 387). Recently, this approach was revived in the concept of serious games. As students obviously are attracted by online games an increase in attractiveness of learning is assumed when delivered in a similar form (Rieber, 1996; van Eck, 2006). It even has been postulated that students who grew up with the daily use of information and communication technologies would develop radically different learning styles. In analogy to browsing behaviour in the internet, with its potential to distract attention and the simultaneous use of different devices, it has been argued that "digital natives" (Prensky, 2001) are highly capable to multitask and moreover can only absorb small bits of information at the same time. As a result it has been suggested that digital natives not only prefer technology-supported learning but are not adequately addressed by traditional didactical approaches: "Technology is altering (rewiring) our brains. The tools we use define and shape our thinking.” (Siemens, 2004). According to Prensky, one way to get the attention of these learners could be developing computer games based on a completely revised and abridged curriculum (Prensky, 2001, p. 4).

Other authors have suggested to no longer seeing knowledge as the outcome of an individual learning process. In connectivism, all individuals together form and have access to a “connective knowledge” (Downes, 2012; p. 299). Connectivism can be described as a further development of early e-learning paradigms and the Web 2.0 approach, with a dominant role of technology in providing access and shaping learning styles. According to this evolutional view, the next milestone was the wide access to university lectures for large numbers of participants in massive open online courses, or MOOCs (Downes, 2012, p. 20). Originally based on an initiative by lecturers at the Massachusetts Institute of Technology MIT, the idea spread rapidly and resulted in a multitude of online courses, not only but mainly from elite universities, that can be accessed without charge. While “anyone with an Internet connection can enroll” (Pappano, 2012) the question of certification remained unsolved. In 2011, for example, Stanford’s MOOC “Introduction to Artificial intelligence” had 160,000 enrolments (Rodriguez, 2012), a participant number certainly not manageable, even if only ten per cent of these students decided to submit coursework.

Finally, digital natives might not be that fundamentally different from previous generations when it comes to learning. Bennett *et al.* (2008b) criticised that the concept of digital natives was mainly based on anecdotal evidence, and has not even been started to be analysed scientifically, let alone proved. While it is considered common thus trivial knowledge that communication technology plays a major role in adolescents’ lives, it will have to be thoroughly investigated if and how this situation affects attitudes towards learning and education. Not all Facebook users are organised in learning communities, and those who are may not necessarily be interested in online games.

> “Young people may do things differently, but there are no grounds to consider them alien to us.” (Bennett *et al.*, 2008b, p. 783)

Nielsen (2010) could show that adolescents' ICT affinity and expertise often were overestimated. He observed the online activities of 43 students (18 to 24 years) from the USA, UK, Australia and Germany. The goal of his study was to analyse how adolescents interacted with different websites and which designs they preferred. While he could confirm that students were familiar with the technology as they used it daily for both educational and private reasons, they did not show extreme proficiency when asked to perform a set of search tasks. Like most adult internet users ("digital immigrants", according to Prensky, 2001), they preferred websites that were designed clearly and did not have difficult navigation paths. The assumption that young people "crave multimedia and fancy design" was disproved; at least when searching for information the study participants felt disturbed by distractions from the design. This was particularly the case for college students who, unlike teenagers, drew a clear distinction between "work" and "play".

When learning, digital natives may be more conservative than expected. Heidenreich (2009) investigated the learning processes of experienced e-learners and found that many personal learning habits were not digital at all, like learning with self-made flashcards or consulting textbooks. Some reasons for this behaviour may become negligible in the future; a broader use of tablet computers, for example, will allow a more independent use of e-learning tools. On the other hand, not all learners prefer technology for all phases of the learning process. Heidenreich suggested that students had personal preferences when learning, and while the majority valued tools supporting self-evaluation and measurement, e.g. self-tests that delivered immediate feedback, there were broad differences in learning styles (Heidenreich, 2009, p. 292ff.).

Concluding, the literature does not deliver strong evidence for the *digital natives postulate* that today's youth has a stronger affinity for e-learning, or game-based learning. At the same time, computer illiteracy or digital divide are not relevant for today's adolescents and familiarity with the use of the internet can be presumed. Reasons to enrol in either e-learning, face-to-face, or blended learning programmes appear to be based on the availability and quality of the learning material (Nielsen, 2010; Persike and Friedrich, 2016) and on personal preferences, for example the interest to meet instructors and peers in “real life” (Biehler *et al.*, 2012, p. 1976). As Heidenreich stated, “learners will use e-learning applications when they consider them beneficial for their learning” (Heidenreich, 2009, p. 252).

### 2.5.2 Learning analytics

While the e-learning assumptions made in the previous section refer to the different learning experience in technology-enhanced learning environments, the field of educational or learning analytics is concerned with the data that are accumulated in such environments. The increased use of information technology in education and research indeed has made it easier to collect “big data” for scientific exploitation.

Large governmental or organisational databases have long been “mined” for demographic or socio-economic statistical analysis, for marketing, or for confirming or aligning management decisions. In the academic field, analytics have been found valuable for operational decision making (Goldstein and Katz, 2005) and for analysing student performance (Wang and Newlin, 2000). “Educational data mining” (Romero and Ventura, 2010) lends itself for diverse research contexts (face-to-face and distance-learning), under differing technical aspects (intelligent tutoring, web-mining, adaptive systems) and its results can be considered relevant for different stakeholders (management, educators and students). In particular, technology is helpful for collecting different types of learner data (Gibson and Ifenthaler, 2017).

Van Barneveld *et al.* (2012) suggested to differentiate between (a) academic analytics, (b) learning analytics and (c) predictive analytics: Academic analytics are comparable to the goals and principles of business analytics and therefore mainly address management in higher education and/or educational policy. Learning analytics refer to evaluation and analysis of teaching and learning methods and help making instructional and curricular decisions. Finally, predictive analytics are used to model predictors of student performance. Campbell and Oblinger, for example, advocate the use of all available student data - SIS (student information system) data, LMS log files, marks and grades - for detection of indicators for success, or failure. Knowing these would make it easier to “alert key stakeholders, and suggest interventions” (Campbell and Oblinger, 2007, p. 1).

Most interventions address the issue of student withdrawal. With an increasing number of students not completing their course, the idea is to develop “early warning systems" (Greller and Drachsler, 2012) that allow to inform students before they have failed several exams and it may be too late for remedial action.

Based on such considerations, Marbouti *et al.* (2015; 2016) compared different methodological approaches to predicting study success in engineering. They collected comprehensive data from a first year course, from quizzes to mathematical modelling to team work participation to written exams. The model with the highest predictive power was able to predict success (course completion or failure) with 85% accuracy (Marbouti *et al.*, 2016, p. 9). Compared to other attempts to predict tertiary achievement (see also section 2.1.2), this model was extremely precise. It needs to be stated, though, that these analyses targeted only one particular course (with an average pass rate above 90%) and the authors admitted that any change to the course design would probably affect the model's quality. Thus it seems questionable if the amount of collected data and the complexity of the model estimations can be transferred to a more general estimation of engineering performance.

Most projects attempting to address "at risk" students use data that are already available, for example the university's administrative data base. At Stuttgart Media University, a system constantly tracks learning outcomes and automatically invites them to a counselling session once their scores drop to a predefined "red" area (Metzger *et al.*, 2015). Corrigan *et al.* (2015) used the data collected from Dublin City University's learning management system. Based on their log files, participants of the study were notified on a weekly basis how often they had accessed the LMS; if applicable, they were encouraged to do more. The authors observed higher average grades in the group of study participants, compared to students who did not participate. The study had no experimental design, therefore these differences could not be ascribed to the constant "nudging"; however, in the evaluation many students claimed that the system had indeed helped them to study more and on a regular basis.

While the availability of learner data has grown it is not yet clear which of the collected data deliver useful or meaningful information. In a case study by Rogers *et* *al.* (2010), for example, web analytics were used to explore student behaviour in an online algebra course. Based on log files, average page views per visit, and average pages per lesson students' learning paths were found to be mainly linear; furthermore students' learning activities decreased throughout the study. The study interest had been to improve the design of the course; however, the quantitative evaluation alone could not explain why students had shown this behaviour, suggesting that much more and probably qualitative information was needed to clarify these outcomes.

It therefore seems reasonable to identify e-learning variables that can be related to learning outcomes or student performance. Macfadyen and Dawson (2010) evaluated how learning activities in an undergraduate biology online course were correlated with course performance. The authors had expected that highly engaged students would spend more time with the online material and perform better on the final tests, but the linear correlation between time spent online and student performance was rather weak. There was, however, a significant relation between the number of completed formative assessments and achievement. An even higher significance was found for the number of contributions to course discussion forums, suggesting that active participation was a good indicator of student engagement in this course.

For an introductory science course Samson (2015) analysed the informational value of data collected from an e-learning platform. While the strongest predictors of exam grades were students' incoming GPA he also found positive correlations between performance and the number of questions a student had answered on the platform. By comparison, mere course attendance was unrelated to achievement.

Thus the kind of learning activity can be considered relevant for modelling student learning; however, the data that can be collected from common learning management systems are not very sophisticated. To date, the ability of educational technology to adequately describe the learning process has only been explored theoretically (Schumacher and Ifenthaler, 2018).

A study by Azevedo *et al.* (2010), for example, demonstrated the challenges that arise from the attempt to measure cognitive and metacognitive processes. While in the future such systems may be available the authors claimed that, to fully grasp students' learning activities, log files needed to be enriched with qualitative data sources like think aloud protocols, videos, or eye tracking. Kinnebrew *et al.* (2014), as well, reported high conceptual challenges regarding a meaningful interpretation of students' use of learning strategies based on tracking data. While they were able to demonstrate differences between strategy use in different experimental conditions they could not relate these differences to learning outcomes.

Concluding, some challenges or even negative effects of the learning analytics approach should be considered. Campbell and Oblinger suggested that if all student data were constantly collected and analysed, students might get the impression of being observed by a "big brother". Therefore high standards of data privacy need to be applied. Furthermore, it needs to be discussed if "predicting" study success might have negative effects, for example by demotivating and frustrating "at risk" students, or by giving "good" students a false sense of security.

From the perspective of researchers (and organisations that commission predictive analyses) the possibility of error needs to be accounted for (Campbell and Oblinger, 2007, p. 17). Learning analytics offer many possibilities for statistical analysis and the mere amount of data might tempt researchers to "believe" them. If unrelated to qualitative information the value of collected learner data thus might be low and the often laborious process of data mining result in a "large amount of data in a meaningless form." (Elias, 2011, p. 7).

### 2.5.3 Tools to support self-regulation

While learning technology provides many opportunities for activating and engaging instructional designs it has also been suggested that not all students may benefit from technology-based learning in the same way.

While the time- and place independency of e-learning allows addressing large heterogeneous groups of learners, its openness may result in a lack of structure and guidance. It was found, for example, that completely explorative und nonlinear learning environments may overwhelm and frustrate learners, particularly when they are new to the domain or when they lack the ability to self-regulate.

Research on self-regulation in web-based environments has thus analysed how differences in students' (e-)learning behaviour affects learning outcomes and how students' use of learning strategies might be fostered by design. E-learning environments may provide overviews and visualisations of the structure of the learning contents, help tools, or metacognitive prompts that are only activated when learners experience problems. Instructional "scaffolding" (Vygotsky, 1978; Bruner, 1978) refers to guidance and help in situations where the learner is no longer able to navigate the environment independently but needs a hint how to proceed.

Azevedo *et al.* (2004a; 2004b), for example, investigated if self-regulation in e-learning can be fostered by giving metacognitive prompts. College students and undergraduates took part in e-learning sessions on science topics (circulatory system and ecology systems); the learning process was recorded with think-aloud protocols and the effect of the learning process on students' mental models of the topic was assessed with a post-test. The researchers compared two scaffolding conditions, "fixed" and "adaptive", with a control group that did not receive any metacognitive scaffolding. The e-learning environment in this study provided a "fixed" scaffold, meaning that students had access to additional information on a certain topic. The "adaptive" scaffold was a human tutor who was there to answer students' questions, but also observed their activities and gave hints if applicable.

Students in the adaptive scaffolding conditions strongly relied on the tutor and efficiently made use of the learning strategies he had suggested. They also developed a deeper understanding of the topic. By comparison, the fixed scaffolding condition appeared to be effective only for some of the students. The authors suggested that the fixed scaffold interfered with inexperienced students' "ability to develop sophisticated mental models of the topic" and might only be helpful for learners that already had developed self-regulated learning strategies. The control group in this study did not make use of self-regulatory strategies; their learning gains, however, were similar to the other groups. The authors concluded that adaptive online help systems were promising in theory, but in practice too limited to "fully emulate the scaffolding used by the human tutors" (Azevedo, 2005, p. 205).

Other authors reported that students failed to use cognitive tools in the intended way. In a study evaluating students' tool use in a computer-based learning environment participants were allowed to access additional information or help while working on a diagnostic problem (Clarebout *et al.*, 2004). Surprisingly, most students did not make use of these tools, even when experiencing problems with the task. Analysis of thinking aloud protocols showed that participants were reluctant to seek help, as they thought they would be cheating if they used the tools. The authors concluded that students' conception of instruction and how a learning process should be enacted might interfere with too sophisticated instructional designs.

Other interferences were observed by Narciss *et al.* (2007). In their study on psychology students' use of navigation tools in a web based course, participants were reluctant to seek help, so that most of the time "these tools remained virtually unused." (Narciss *et al.*, 2007, p. 1140). The learning techniques students applied in the online environment were similar to those they would apply with (printed) textbooks, indicating that familiar learning strategies are quite persistent, or that the tools did not adequately address students' needs.

These examples show that emulation of human scaffolding in e-learning environments has not been fully achieved. Adaptive systems still are very limited in their capacity to "understand" students' misconceptions and address them adequately and students may have to learn how to use these systems.

In a study with 9th grade high school students Kramarski and Gutman (2006) showed that learners who were provided with additional metacognitive training (based on Mevarech and Fridkin, 2006) achieved significantly higher learning gains in a web-based mathematics course than students who did not.

McManus (2000) suggested that nonlinear environments that tempt students to explore might be problematic for students with low ability to self-regulate, whereas environments offering too little choices were likely to constrain learners with high levels of self-regulation.

These results were supported by Azevedo *et al.* (2008), Moos and Azevedo (2008), as well as Greene *et al.* (2010). All authors stressed the role of cognitive overload when students were given too much choice in the learning process, or when combining cognitive and metacognitive learning processes. Greene and Azevedo summarised that "for students who lack the skills to self-regulate, providing them with a high degree of responsibility for guiding their learning can be more detrimental than providing a clear guide or scaffold" (Greene and Azevedo, 2007, p. 343).

It therefore needs to be pointed out that the group of "at risk" students, who lack basic knowledge in the domain of mathematics, are also very likely to lack metacognitive knowledge about the effective use of learning strategies (see chapter 2.3). Too elaborate help systems that add to cognitive load thus may even hinder learning (Sweller, 2005; Kalyuga *et al.*, 2003).

### 2.5.4 Formative assessment to initiate and monitor learning

One major advantage of learning management systems are the built-in test tools that allow to provide learners with different forms of automated feedback. Instructors are relieved from the load of marking hundreds of exercises whereas students appreciate the immediate response of the system (Whitelock, 2008; Heidenreich, 2009; Sangwin, 2012). Their interactive nature makes e-assessment tools also useful elements of didactic scenarios.

Vandecandelaere *et al.* named “four dimensions for creating powerful learning environments”: (1) Motivation to learn, (2) Activate self-directed learning, (3) Feedback and coaching, and (4) Structure and steer (Vandecandelaere *et al.*, 2012, p. 109). Winne (2004) stressed the importance of calibration for the self-study process, and of giving learners all the relevant information they need. In this section methods to provide this information and to support self-study processes are discussed, with an emphasis on the role of formative e-assessment.

In distinction to summative forms of assessment that are connected to grades, formative assessment is a way of monitoring a learner’s level of knowledge at a specific moment in the learning process. It provides instructors and learners with an overview of the actual knowledge level of a group or an individual. By definition, “formative assessment is a systematic process to continuously gather evidence about learning” (Heritage, 2007, p. 141). Without this evidence, misconceptions may remain unnoticed for quite some time by instructor and learner. Formative assessment helps creating a “cognitive conflict” (Black and Wiliam, 2009, p. 19) that can be resolved before instruction proceeds, or misconceptions are revealed in summative forms of assessment. Black and Wiliam (1998) suggested that instead of the commonly practised “assessment *of* learning” schools should focus on “assessment *for* learning” and use formative assessment as a means to engage and activate learners. According to the authors, the two major functions of formative assessment are (1) drawing attention to a gap between learning goal and actual level of knowledge and (2) providing with possible courses of action to close this gap (Black *et al.*, 2003). Learning can be initiated if a learner considers this gap as manageable. It should neither be too large and overburdening, nor too small as “closing it might be considered not worth any additional effort.” (Sadler, 1989, p. 130). A major task when using formative assessment in a didactic setting therefore is to address this gap with questions of adequate difficulty and complexity (Heritage, 2007).

For the use of formative assessment in the classroom, Shavelson *et al.* differentiate between more or less spontaneous “on-the-fly” formative assessment sessions, “planned-for-interaction formative assessment” which serves as an impulse or activating method and, finally, “curriculum-embedded” formative assessment which refers to predefined learning goals and thus, more or less directly, to ensuing summative assessments (Shavelson *et al.*, 2008, p. 300-301). Transferred to e-learning environments, one can differentiate between

1) *Formative assessment that initiates and monitors learning* by providing diagnostic information at the beginning and tools to measure progress at the end of the learning process. These types of assessment are mainly related to “curriculum-embedded formative assessment” as they enable students to monitor their learning in reference to the learning goals of the programme.
2) *Formative assessment that activates and motivates throughout the learning process.* These types of assessment are more strongly related to “on-the-fly formative assessment” and, dependent on the didactical design, “planned-for-interaction formative assessment” (Shavelson *et al.*, 2008), p. 300-301). Both the role of exercise for successful learning and the importance of interaction for student retention are postulated.

In e-learning environments, students have a higher level of responsibility for their learning and thus should be enabled to administer assessments, as well (Nicol and Macfarlane-Dick, 2006). Before engaging in the learning process they need to be informed which learning contents will be delivered throughout the course and how these compare to their individual knowledge level. Diagnostic self-tests support this “calibration” (Winne, 2004) and make the learning goals of a course transparent to learners (Jacobs, 2008, p. 100).

“Good feedback” will inform on background and goals of the assessment and help to decide on subsequent actions (Nicol and Macfarlane-Dick, 2006). However, when delivered automatically, diagnostic feedback may not always be as meaningful as required and students might need metacognitive support.

It has been subject to discussion, for example, if formative assessment should provide scores or grades. Black *et al.* (2003) suggested that rating systems would discourage poor performing students, provoke a stronger performance orientation (Dweck, 1986), and pre-empt other feedback elements, like hints, or suggestions for further learning (Brennan, 2006; Black *et al.*, 2003; Gibbs and Simpson, 2004). On the other hand, students may feel patronised when they are not informed how their test feedback was computed (Nicol and Macfarlane-Dick, 2006).

Diagnostic feedback certainly should be expressed objectively and not threaten students' self-esteem. In a meta-analysis on the effectiveness of feedback interventions, Kluger and DeNisi could show that any feedback referring to students' self-esteem, be it "discouraging" or exaggerated "praise", was likely to induce negative learning outcomes (Kluger and DeNisi, 1996, p. 254). Positive effects could be found for "velocity" feedback, "correct solutions", and computer-based feedback (ibid., p. 273).

Self-diagnoses at the beginning (and the end) of the learning process are important components of the self-study process. Diagnostic tools inform learners and help them to structure the ensuing learning process. The role of diagnostic feedback is of particular importance when course participants are diverse regarding their domain-related knowledge level and their ability to learn self-directedly. Each student should be able to interpret their test result without being demotivated, but the importance of transparency and awareness of existing knowledge deficits should also be acknowledged (Croft *et al.*, 2009). Finally, each additional (meta-) information will absorb attention and add to students' cognitive load. Thus authors have to be especially concerned with the design and composition of feedback contents.

#### 2.5.4.1 Simplistic problems and acquisition of skills through practice

In learning theories the role of practice is often treated in a cursory manner; its importance is usually acknowledged but not further investigated (Bollnow, 1978). Practice, or exercise, are associated with behaviourist views on learning, “drill&practice” programmes, memorisation, and rote learning (Bönsch, 2014). The “ascetic” character of practice (Brinkmann, 2011, p. 140) and the focus on repetition appear to be in contrast to explorative and constructivist approaches to learning (ibid., p. 144).

In psychology, the role of deliberate practice has found some attention regarding the development of expert performance. It was shown that mastery was much more dependent on time spent practising than on individual talent (Ericsson *et al.*, 1993). When practising, for example a musical instrument, the learner will repeat one single section of a melody until it is mastered, then proceed to the next element until finally combining all elements to a piece of music. Until perfection, this process may demand hundreds of repetitions which are “meaningless in themselves” (Bollnow, 1978, p. 40). Accordingly, a proficient use of mathematics demands that basic concepts have been practised and internalised, so that they can finally be integrated into more complex problems without effort.

Regarding learning processes it has been suggested that practice should be designed to target students’ weak areas, or, put positively, “this just right gap” (Heritage, 2007, p. 141). Pachman *et al.* (2013) investigated the impact of practice on eighth grade high school students’ performance in geometry. Based on the observation that students prefer to answer very easy items, the authors hypothesized that a precisely tailored practice programme would lead to more efficient and successful learning. For her dissertation, the first author compared learning gains of two groups of students: participants of the experimental group received an individually designed practice regimen, based on their results in a diagnostic test. Students in the control group were free to choose which kind of problems they wanted to practice with. The authors found that strongly focused learning activities were only beneficial for students with an existing basic knowledge; these students significantly outperformed the control group students in a post-test. Students with a very low prior knowledge level, however, benefitted more from solving many “easy” mathematics problems, regardless of their “problem areas”. The authors suggested that addressing multiple weak areas in a relatively short period of time might overburden students (Pachman *et al.*, 2013). Thus complexity can also be generated by the provision of too many simple problems.

Concluding, the importance of practice for the acquisition of basic mathematical skills is acknowledged. It is also postulated that a competent use of basic mathematical skills is required to answer more complex problems (as addressed in the following section). It is also emphasised that practice is not limited to simple tasks, as

> “probably the only way to learn how to solve problems is to solve lots of problems.” (Gibbs and Simpson, 2004, p. 15)

#### *2.5.4.2 Complex and realistic problems and the motivation of learners*

A positive attitude towards mathematics may be helpful when choosing a STEM-related degree programme, but studies have shown that engineering students’ attitude towards mathematics not significantly differs from that of the general student body (Berkaliev and Kloosterman, 2009). Mathematics is not the main interest of engineering students, thus motivational issues may arise when they are asked to recapitulate learning contents from secondary school.

In the field of mathematics teaching for engineers, the provision of examples illustrating the application of mathematics in the domain of engineering has been suggested as a potential remedy. Kendall Brown *et al.* (2009) advised lecturers to expose students to “real-world” applications as one of four teaching activities to prevent student attrition. They also suggested presentations of careers in engineering, helping students envision the final goal of their efforts. Similarly, Rylands *et al.* (2013) described a project to increase science students’ interest in mathematics by stressing the practical relevance of the course content for their chosen career. The authors claimed that instructors in mathematics and science had different teaching cultures, and that mathematicians were reluctant to offer examples for “real world” applications. As a conclusion the authors stressed the importance of more and more curriculum-centred communication between disciplines (Rylands *et al.*, 2013, p. 842).

Preißler *et al.* (2010) evaluated a cooperation between educational and technical faculties. In an attempt to increase student motivation, the first year mathematics lecture for mechanical engineers was revised. The curriculum was moderately changed, face-to-face instruction time was reduced, and lectures were enriched by practical examples from engineering, accompanied by a voting system based on Mazur’s work (*Note:* in the concept of clicker lectures, mathematical problems are presented at the beginning of the lecture, students then vote which answer they think is correct. After a phase of group work and a second voting session the correct result is announced and discussed, see also Mazur (1997)).

Young *et al.* (2011), as well, developed a modular programme consisting of practical examples and clicker lectures, plus a set of social and didactical activities. The goal of the “EXCEL” programme was to minimise drop-outs and make students become part of a learning community. The most important success, according to the authors, was that students highly appreciated the connection of science and engineering with mathematics and that the project had helped them to “feel that I am a member of an EXCEL learning community” (Young *et al.*, 2011, p. 601). A similar approach to prevent attrition was suggested by Kendall Brown *et al.* (2009).

These examples show that connecting mathematics with engineering problems eventually may increase motivation of first year students, supporting both constructivist and social-constructivist views that the value of mathematics may only be grasped by relating it to problems relevant for students’ personal lives (Lave and Wenger, 1991; Palincsar, 1998; Molenaar and Järvelä, 2014).

However, it may be difficult to develop meaningful engineering examples that can be solved by students that yet have to study basic mathematical principles. Härterich *et al.* (2012) and Rooch *et al.* (2014) developed a project addressing first year “at risk” students, called “Mathepraxis”. Guided by a tutor, small groups of students intensively worked on “real” engineering problems (balancing of a Segway, developing a control system for cranes). As the authors pointed out, these problems were too complex to be solved with first year students' prior knowledge. Therefore each problem had to be edited and put in a didactically sound form. Even then, students needed several weeks to solve these problems, therefore the concept could not be implemented into the general mathematics lecture.

In a secondary school context, Offer and Bos used a commercial e-learning software to investigate if the provision of real-world problems would foster mathematics learning of high school students. The software's design followed a problem-based learning approach; for example, students were asked to develop a speeding fine structure for their virtual neighbourhood. Although the overall acceptance of the software was quite high, both teachers and students complained about the "lack of relevance" of the problems provided by the software (Offer and Bos, 2009, p. 1135). Furthermore, the programme's assessment was found too difficult and time-consuming for most students so that an impact on learning gains could not be evaluated.

The major challenge of this approach appears to be finding the balance between "real world" and idealised mathematical problems. Whereas realistic contexts may increase students' interest they also bear the risk of digressing from the core of the problem and increasing study time. With growing complexity the danger of misinterpretation grows, as well. Without support from tutors or lecturers an overcomplex problem may become unsolvable and thus lead to demotivation.

It also may not be self-evident that students with a negative attitude towards mathematics will benefit from this approach. Poladian, for example, tried to increase the attractiveness of basic mathematics lectures for science students by giving examples from the field of biology, psychology, or medical science. Although the academic performance of participants in this course could be increased the evaluation revealed that their attitude towards mathematics (and practical examples) was not affected by the project. The authors suggested that students' perception of a mathematical problem was rather influenced by their individual experiences and attitudes than an "objective measure of relevance." (Poladian, 2013, p. 873).

It thus can be stated that engineering examples have the potential to increase motivation to learn mathematics, but some limitations should be considered. A direct impact on achievement, motivation or attitude has been found difficult to measure (Poladian, 2013; Offer and Bos, 2009), and some observations suggest that mainly good (and already motivated) students are attracted by this approach (Rooch *et al.*, 2014). It also has been found difficult to clearly identify what makes a "real world" problem and at which point the didactical adaptation has rendered it "artificial". It might even be irrelevant for students who certainly are aware that their "community of practice" is one of engineering students and not one of engineers. As Carraher and Schliemann pointed out, "staging" of problems was an important element of teaching

> "because naturally occurring everyday situations are not sufficiently varied and provocative to capture the spectrum of mathematical inquiry."
> (Carraher and Schliemann, 2008, p. 9)

Problems should be meaningful for the learner, for example illustrate situations where a certain mathematical approach is useful. They should also be solvable in a reasonable period of time and without provision of too much additional information; therefore they have to be simplified.

### 2.5.5 Conclusion

The use of e-learning environments has been suggested as one viable approach to address heterogeneous groups of learners, as they allow for individual and self-paced learning. Students with different knowledge levels can follow different learning paths, and they are free to do so at any time and place. A higher level of individuality, however, demands a higher level of responsibility from students, increasing the importance of self-regulation. Students who find it difficult to self-regulate thus are likely to benefit from support and guidance (Winters *et al.*, 2008)

Tools that foster the development of learning strategies have been found quite limited in their capacity to "understand" students' misconceptions and address them adequately (Azevedo, 2005; Narciss *et al.*, 2007). It thus seems more beneficial to focus on the useful implementation of formative e-assessment - in combination with human tutoring.

Regarding information, calibration, activation, and motivation of students in the self-study process formative e-assessment plays an important role (Winne, 2004). The advantages of automated feedback are acknowledged (Whitelock, 2008; Heidenreich, 2009; Sangwin, 2012) and it is considered one major challenge of the design of e-learning environments to provide students with meaningful feedback (Nicol and Macfarlane-Dick, 2006).

Finally, the role of social interaction for successful learning processes needs to be accounted for. Social constructivist approaches promote the use of cooperative learning platforms, with students exchanging information and discussing problems (Wenger, 1998; Kahnwald, 2013). Reflection and communication has also been found to support mathematics learning (Mevarech and Fridkin, 2006) and was successfully implemented in e-learning environments (Kramarski and Gutman, 2006). Limitations to this approach have been found regarding students' preparedness or willingness to communicate in public or semi-public forums (Kempen, 2016). Fear of exposure may prevent especially those students from participation who have large domain-related knowledge gaps or experience problems with language or writing.

## 2.6 Conceptualisation of student learning

In this chapter different approaches to measuring personal and behavioural variables as well as learning outcomes are discussed. Models of self-regulated learning acknowledge the importance of cognitive, metacognitive and motivational-emotional components and their intercorrelation. As it is not possible to operationalise or "measure" self-regulated learning, it is usually addressed by questionnaires. Other studies have relied on learning diaries and more recently the role of learning analytics has come into focus (see section 2.5.2).

### 2.6.1 Measurement of attitude towards mathematics

Based on the literature review and the perceived relevance of attitudes for the learning process information on prospective engineering students' attitudes towards the subject of mathematics was to be collected.

Since the 1970s, many suggestions for operationalisation and measurement of attitudes towards mathematics have been made; it seems that no other school subject has received similar attention when it comes to affective and motivational obstacles to learning. In his review on inventories addressing affect in mathematics, Chamberlin claimed that, in the face of a "myriad of instruments", a comprehensive list of existing inventories could not be provided (Chamberlin, 2010, p. 171). Accordingly, this chapter will only give a brief summary of the most often quoted scales, in chronological order.

Richardson and Suinn's "Mathematics Anxiety Rating Scale MARS" (1972), and Aiken's "Mathematics Attitude Inventory" (1974) aimed at emotional dispositions in relation to mathematics, Aiken's scale being enhanced by a "value of mathematics" scale that represented learners' perceptions of the importance of mathematics. In the "Fennema-Sherman Mathematics Attitudes Scales" (1976) this part was referred to as "mathematics usefulness scale". The whole inventory consisted of nine subscales, e.g. "attitude towards success in mathematics scale", "confidence in learning scale" or "mathematics as a male domain scale".

Galbraith and Haines (1998) developed a similar scale, consisting of subscales like "mathematics confidence", "mathematics motivation" and "mathematics engagement", but added the factors "computer confidence" and "computer-mathematics interaction". This relation between mathematics and computer-use was also drawn by Fogarty *et al.* (2001). Their "Attitudes to Technology in Mathematics Learning Questionnaire ATMLQ" was extended by another subscale that addressed the use of graphic calculators. Similar aspects were included in Pierce *et al.*'s "Mathematics and Technology Attitudes Scale MTAS" (2007). While these questionnaires were designed for primary and secondary school students, Fogarty *et al.* (2001) developed a scale for tertiary education, combining mathematics confidence, confidence with using technology in general, and attitudes towards technology or tool use in mathematics, the "Attitudes to Technology in Mathematics Learning Questionnaire ATMLQ".

In the "Attitudes Toward Mathematics Inventory ATMI" by Tapia and Marsh (2004) computer use was not included; it comprised eleven subscales addressing topics like "self-confidence", "enjoyment of mathematics" and "motivation", and, reintroducing, "value of mathematics".

For the "Trends in International Mathematics and Science Study TIMSS" a three-dimensional model was developed, covering "LM liking mathematics", "SCLM self-confidence in learning mathematics", and "VM value mathematics" (Kadijevich, 2006). The model was slightly changed in the course of the project (Martin *et al.*, 2012; Mullis *et al.*, 2012), and in some countries the items were combined with other sets of items (e.g. Vandecandelaere *et al.*, 2012).

All the above named instruments use 4- or 5-step Likert-type scales, listing statements that describe an individual's thoughts or feelings. Though different in structure and focus, these scales have many similarities as most authors referred to existing scales and often only gradually changed single statements or combined them into different subsets. The following table shows an overview of the categorisation of characteristic items in a choice of scales and subscales.

| Statement | Subscale | Scale | Authors | item # |
| --- | --- | --- | --- | --- |
| *I can get good results in mathematics* | mathematics confidence | Attitude to mathematics and technology | Galbraith and Haines (1998) | 40 items (5 scales) |
| | | MTAS | Pierce *et al.* (2007) | 20 items (5 scales) |
| *I usually do well in mathematics* | mathematics confidence | TIMSS | Mullis *et al.* (2012) | 20 items (3 scales) |
| *I have a lot of confidence when it comes to mathematics* alternatively: | mathematics confidence | Attitude to mathematics and technology | Galbraith and Haines (1998) | 40 items (5 scales) |
| *I am confident with mathematics* | | MTAS | Pierce *et al.* (2007) | 20 items (5 scales) |
| *I am able to solve mathematics problems without too much difficulty* | self-confidence | ATMI | Tapia and Marsh (2004) | 49 items (4 scales) |
| *I have less trouble learning mathematics than other subjects* | mathematics confidence | ATMLQ | Fogarty *et al.* (2001) | 30 items (3 scales) |
| *I have a mathematical mind* alternatively: | mathematics confidence | MTAS | Pierce *et al.* (2007) | 20 items (5 scales) |
| *I do not have a mathematical mind* | | ATMLQ | Fogarty *et al.* (2001) | 30 items (3 scales) |
| *Mathematics is a subject I enjoy doing* | mathematics motivation | Attitude to mathematics and technology | Galbraith and Haines (1998) | 40 items (5 scales) |
| *Learning mathematics is enjoyable* | affective engagement | MTAS | Pierce *et al.* (2007) | 20 items (5 scales) |
| *I have usually enjoyed studying mathematics in school* | enjoyment | ATMI | Tapia and Marsh (2004) | 49 items (4 scales) |
| *I enjoy learning mathematics* | liking mathematics | TIMSS | Mullis *et al.* (2012) | 20 items (3 scales) |
| *I like to stick at a mathematics problem until I get it out* | mathematics motivation | Attitude to mathematics and technology | Galbraith and Haines (1998) | 40 items (5 scales) |
| *If I make mistakes, I work until I have corrected them* | behavioural engagement | MTAS | Pierce *et al.* (2007) | 20 items (5 scales) |
| *I concentrate hard in mathematics* | | | | |
| *I find working through examples less effective than memorizing given material* | mathematics engagement | Attitude to mathematics and technology | Galbraith and Haines (1998) | 40 items (5 scales) |
| *Mathematics is important in everyday life* | value mathematics | ATMI | Tapia and Marsh (2004) | 49 items (4 scales) |
| *I think learning mathematics will help me in my daily life* | value mathematics | TIMSS | Mullis *et al.* (2012) | 20 items (3 scales) |

*Table 4 Examples for attitude towards mathematics items, addressing confidence, feelings, engagement, and value*

The items listed in Table 4 show that some dimensions, or subscales, can be found in every inventory, for example “self-confidence”, or “mathematics confidence”. It describes a student’s self-perception in relation to mathematics or mathematics learning and is expressed through items like “I usually do well in mathematics” from TIMSS, or “I have a mathematical mind” (MTAS). Another very frequent dimension is liking or disliking mathematics, referring to positive or negative feelings, e.g. “Mathematics is a subject I enjoy doing” from the “Attitude to mathematics and technology” inventory. As students might not particularly “like” mathematics but still acknowledge its general importance, the dimension “value mathematics” is also often used. In these items the role of mathematics outside the school environment is addressed, for example “I think learning mathematics will help me in my daily life” from TIMSS.

Concluding, most inventories show very similar operationalisation of attitudes towards the subject but with different emphases. As the participants of this study had not yet entered tertiary education it appeared appropriate to use the attitude subscales from the Trends in International Mathematics and Science Study TIMSS (Kadijevich, 2006; Mullis *et al.*, 2012).

### 2.6.2 Measurement of learning strategy use

Many of the attitudes scales that were discussed in the previous section also comprise variables related to the use of learning strategies. Other authors have modelled learning strategy use as an overarching construct. One well-known example is the “Motivated Strategies for Learning Questionnaire MSLQ” (Pintrich and de Groot, 1990; Pintrich *et al.*, 1991). Its overall 81 items refer to students’ motivation, self-confidence, and the use of learning strategies, e.g. efforts put into learning, time management and organisation of the learning environment. Based on the MSLQ, Schiefele and Wild developed a German inventory called “LIST *Lernstrategien im Studium*” that was especially designed for tertiary education (Schiefele and Wild, 1994; Wild, 2000). The authors translated the American items and modified those not compatible to a German context; they also added items that addressed peer learning. The LIST inventory’s internal consistency was tested by the authors, and based on these results they defined the following main categories: (1) organisational strategies, (2) elaboration strategies, (3) memorisation strategies and (4) metacognitive strategies, like planning, controlling, effort regulation, and time management (Schiefele and Wild, 1994). For other applications of the LIST inventory, see Boerner *et al.* (2005), Preißler *et al.* (2010), or Dehling *et al.* (2014).

While LIST and MSLQ address students at university, respective college level, other inventories investigate into younger students' personal attitudes and learning strategies, namely the "Study Process Questionnaire SPQ" (Biggs, 1976), the "Inventory of Learning Processes" (Schmeck and Ribich, 1978), the "Approaches to Study Inventory" (Entwistle and Ramsden, 1983), and the "Study Attitudes and Methods Survey" (Michael *et al.*, 1988). Finally, Barnard *et al.* (2009) used the MSLQ to develop an inventory investigating the self-study process in online learning environments.

The MSLQ and its subsets have been used in numerous studies; a meta-study by Credé and Phillips found more than 150 studies using this inventory and claimed that until today "tens of thousands of students have ... been evaluated on the MSLQ" (Credé and Phillips, 2011, p. 338). Good correlations between the use of learning strategies and academic achievement have been observed for subscales related to time and study environment, e.g. "I usually study in a place where I can concentrate on my class work.", or "I find it hard to stick to a study schedule." (Pintrich *et al.*, 1991). By comparison, the meta-study carried out by Credé and Phillips revealed quite heterogeneous results regarding task strategies like rehearsal, elaboration, or peer learning, which appeared to be "largely unrelated to academic performance" (Credé and Phillips, 2011, p. 344).

For this study it was decided to focus on effort regulation, time management and organisational strategies and to use items from the LIST learning strategies subscales "Cognitive and metacognitive Strategies" and "Resource management strategies" (Schiefele and Wild, 1994). These subscales comprise items like "I worked out my own learning schedule", or "Even if learning was hard, I finally managed to achieve what I had planned".

### 2.6.3 Measurement of prior domain knowledge and learning gains

Students’ prior knowledge level in mathematics as well as their learning gains in the pre-course were at the core of this investigation, but for the German secondary school curriculum no standardised web-based pre-post-test design exists. Thus a methodological approach to evaluate the quality of the test items used in this study was needed. A probabilistic statistical method was chosen that allowed to identify items that emerged as extreme outliers or were “unfair” to certain groups of participants. The general background of IRT models is described in this final section. The item analysis in itself is reported in the pre-study, section 5.2.5.

Test reliability in Classic Test Theory, CTT, demands “parallel measures” (Hambleton and Swaminathan, 2010, p. 2), meaning that two similar tests have to be taken by the same sample under equal conditions, a demand for test development that is not easy to meet. Volunteers for mathematics tests that take the task seriously are hard to find, especially if they are supposed to be representative of the highly heterogeneous target group. A pragmatic method was needed that helped to single out unfit or unsuitable items and to develop internally consistent tests

Classic test theory does not provide models that account for the individuality of participants and their differing abilities when confronted with items that measure different traits. CTT’s demand for representativeness of the sample is based in experimental research, but does not resolve issues of test design, test assessment and item discrimination (Hambleton and Swaminathan, 2010, p. 2f.). In Item Response Theory (IRT) models of item difficulty, participant performance, and participant ability are related to each other in an interdependent equation. Common to these models is the change of focus from overall test score to item properties, expressed as difficulty level and discriminating power. The probability that a participant will answer an item correctly is thus influenced by these properties, in relation to his or her ability.

Item Response Theory has its roots in the 1940ies and 1950ies, and has since then developed from one-parametric models for dichotomous item formats to models integrating guessing factors, the influence of time limits, the impact of multiple-choice distractors, and differing solving strategies (van der Linden and Hambleton, 1997). IRT has been used as a methodological approach for large scale educational surveys, e.g. the US-American “National Assessment of Educational Progress NAEP” (Bennett *et al.*, 2008a) or the “Trends in International Mathematics and Science Study TIMSS” that is based methodologically on NAEP experiences (Mullis *et al.*, 2009). TIMSS is an international survey on primary and secondary students’ knowledge in mathematics and science. Starting in 1995, it has been conducted every four years with students from $4^{th}$ and $8^{th}$ grade. To date, 59 nations have participated, though not every country participated continuously (Germany took part in 1995, 2007 and 2011 only, while England and Wales participated in all surveys). For TIMSS, a sophisticated scaling scheme was developed, based on IRT models for both dichotomous and polytomous items. With this approach the whole subject area of mathematics and science is covered, albeit each student only responds to a subset of items. This method is advantageous for both test and item pool administration. From a test designer’s perspective, the model allows to react to unexpected item behaviour. For example, if an item’s difficulty changes considerably in the course of the project, it can be replaced without endangering the overall design (Yamamoto and Kulick, 2000, p. 237).

On a smaller scale, Gleason (2008) reported the application of IRT models for testing and evaluating multiple-choice tests in mathematics. Using the results of two mathematical competitions at US American high schools, the author reviewed each item’s contribution to the information on a participant’s ability. In an iterative process, using item response model tests and successively removing distractors, or items, and evaluating again, the author developed a refined version of the test. Though the number of items was reduced, test quality could be maintained or even increased, as the remaining items had a higher degree of information (Gleason, 2008).

Bennett *et al.* (2008a) used IRT difficulty estimations to compare the difficulty level of paper-based and ICT-based mathematics tests. All test items' difficulties had been predefined by raters, and based on students' test results the difficulty level was estimated using a combination of the three-parameter logistic model and the generalised partial credit model for polytomous items.

The first IRT models, though, were one-parametric, referring to dichotomous item formats where a participant's answer can either be correct (1) or incorrect (0). In 1960, a "structural model for items in a test" was published by Georg Rasch that is today referred to as the Rasch model. The biggest advantage of the Rasch model is its assessability. Model-conformity results can be interpreted as a confirmation of its internal consistency; Rasch modeling thus can be used to examine a test's quality in retrospect (Strobl, 2012). One well-kown example for the application of a multidimensional adaptation of the basic Rasch model is OECD's PISA evaluation (e.g. Rost *et al.*, 2005).

*Basic assumptions of IRT and the Rasch model*

Central to concepts of ability- or latent trait-measurement is that a person's test result is not only related to his or her ability, but to other situational influences as well, like state of mind, state of health, or luck (when guessing is involved). The probability of a person *i* to solve an item *j* is thus dependent on a random variable.

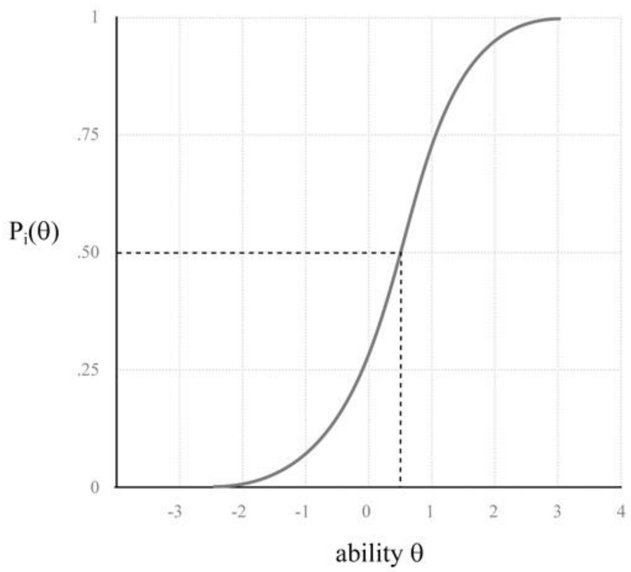



*Figure 5 Item characteristic curve ICC for an item with a difficulty estimate of $\beta$=.5 (the probability of being solved is 50% for a participant with the ability level of .5)*

The Rasch-model describes the probability that a participant with the ability $\theta_i$ solves an item with difficulty $\beta_j$. The difference between these two variables can be positive (ability is bigger than difficulty) or negative (ability is smaller than difficulty), indicating that the Rasch model is based on a logistic function (logit model). A high value on the *x*-axis represents high ability, and a high value on the *y*-axis indicates high solving probability. The higher the participant's ability, the higher the probability that he or she will answer the item correctly. This function can be used to visualise the probability to solve an item in a curve, called the Item Characteristic Curve ICC (see Figure 5). If a participant's ability equals the item's difficulty, the probability to solve the item is 50%.

When several ICCs of a test that has Rasch-conformity are displayed together, the curves of more difficult items will lay on the right half of the *x*-axis, and the easy ones on the left. The steepness of an ICC indicates the item's discriminatory power. If the curve is flat, discrimination between the results of high and low ability participants is low, therefore a steep curve is considered preferable. As shown in Figure 18, the probability to solve an item with high discriminatory power (left) will differ considerably for participants with different abilities (0 and 1) (see also Strobl, 2012, p. 12).

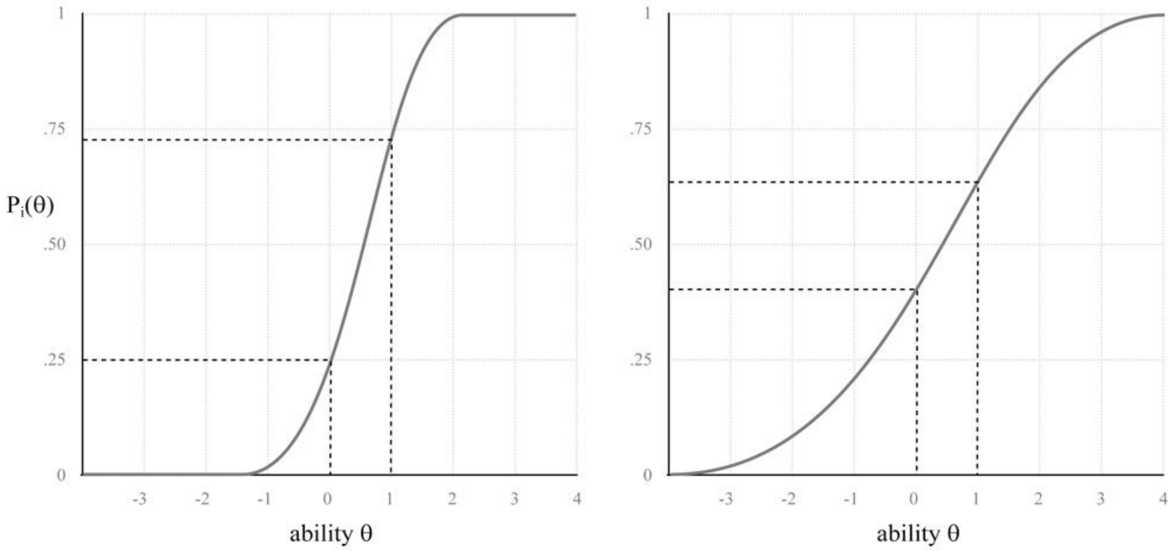



*Figure 6 ICCs for two items with high (left) and low (right) discriminatory power*

One demand of the Rasch model is that all ICCs of a test have equal discriminatory power, thus all curves need to have the same steepness and form, i.e. be parallel. The issue of non-fit items can be addressed by eliminating or replacing items, or by using two- and three parameter logistic models that are a relaxation of the Rasch model (van der Linden and Hambleton, 1997, p. 12).

## 2.7 Gap in knowledge and contribution to theory

At the start of this research the "Quality Pact for Teaching" was launched by the German Federal Ministry of Education and Research (BMBF) and many of the more than 150 participating universities used this funding for the development and implementation of mathematics support centres and preparatory courses (see BMBF online database www.qualitaetspakt-lehre.de and Schmidt *et al.*, 2016). The overall goal of this funding programme, the improvement of tertiary education, is of course difficult to quantify. The literature review gave some examples of the conceptual and methodological problems of analysing open, non-mandatory learning environments. As a consequence, very few projects have made the attempt to comprehensively evaluate the effects of a preparatory course in mathematics.

Many studies reported significant relations between prior knowledge, educational background and first year performance but found it difficult to show pre-course effects based on their data (Abel and Weber, 2014; Greefrath *et al.*, 2016). Other studies that focused on learning behaviour and learning activities either lacked information about participants' prior knowledge, or did not relate outcomes to subsequent study success (Roegner *et al.*, 2012; Vuik *et al.*, 2012; Fischer, 2014). It thus remains unclear if and how participation in a pre-course in mathematics impacts the group of interest, students with broad knowledge gaps in this area. At universities where remedial courses are compulsory for the group of "at risk" students more comprehensive quantitative evaluations have been carried out. For the UK, Lagerlöf and Seltzer (2009) as well as Di Pietro (2012) found only weak or no effects of participation in remedial courses in mathematics on "at risk" economics students' tertiary achievement. A similar lack of effect was reported for US-American universities from Moss and Yeaton (2006), Calcagno and Long (2008), Bettinger and Long (2009), or Ballard and Johnson (2004).

Closing large knowledge gaps in a relatively short period of time demands a lot of effort and metacognitive skills. The literature, however, suggests that students with poor domain knowledge also show lower levels of self-regulation (Weinstein *et al.*, 1988b; Pintrich *et al.*, 1991). Confronted with a high workload, they might feel inclined to use surface learning strategies (Entwistle and Tait, 1990; Crawford *et al.*, 1994; Laurillard, 2005) or they might simply give up and withdraw from the course. Providing extra-curricular learning environments thus might indeed disadvantage the "at risk" group (Clark and Lovric, 2009) and, if "high performers" benefit more from participation (Lagerlöf and Seltzer, 2009), result in even higher student heterogeneity.

The literature gives some suggestions how to address this problem in controlled environments. For the domain of engineering Zimmerman *et al.* (2011) showed how a course particularly designed for first year students with poor domain knowledge in mathematics positively affected their self-regulatory skills and their ability to self-reflect. Similar observations were made by Johnson and O'Keeffe (2016) in a small non-experimental study with non-traditional students. Härterich *et al.* (2012) and Rooch *et al.* (2014) focused on the role of "real life" applications of mathematics to evoke self-reflection and deep learning processes in a small pre-selected group of "at risk" first year engineering students. Finally, Dancer *et al.* (2015) showed how to make "at risk" economics students benefit from peer-assistance in statistics. Such interventions obviously help to close gaps between the "at risk" group and the rest of the student body, but it is unclear how such effects can be transferred from small-scale interventions that are embedded into the first year curriculum to large-scale preparatory courses.

Web-based courses have been suggested as adequate learning environments for heterogeneous groups of learners, but the literature also indicates that inexperienced learners or students with poor domain knowledge may struggle to use them efficiently. A developmental mathematics course evaluated by Ashby *et al.* (2011) showed that withdrawal rates in the online version were much higher than in a face-to-face version of the course. Suggestions for the design of such environments thus stress the importance of additional support and guidance for the "at risk" group (Azevedo *et al.*, 2004a; Winters *et al.*, 2008). Artino and Stephens (2009) also showed that most students entering tertiary education lacked the ability to independently study in e-learning environments and that it would take them until graduation to develop sophisticated self-regulation skills.

Looking for help in such an environment, for example, is an important task strategy; it also could be shown that peer learning and interaction with others contribute to the ability to reflect upon the learning process and develop deep approaches to learning. At the same time, the literature suggests that "at risk" students find it much more difficult to identify the need for support (Karabenick and Knapp, 1991; Newman, 2002) and they also are less likely to consider themselves "at risk" (Besterfield-Sacre *et al.*, 1997; Bol and Hacker, 2001; Zimmerman *et al.*, 2011). It is thus unclear what kind of support is needed most strongly in the case of study preparation.

Considering the issue of procrastination, Plant *et al.* (2005) stated that for the group of "at risk" students effort-related variables and study time might be more relevant than for other learners. Kolari *et al.* (2008), as well, suggested to monitor the time learners invested into studying. According to their observations, "at risk" engineering students spent much less time learning than expected. Thus different sets of variables might be relevant for predicting different types of learners' study success.

Preparatory courses in mathematics provide a self-contained environment that allows observing such interactions. To the knowledge of the author, it has not yet been shown what particular design-related factors (if any) can be related to "at risk" students' subsequent academic performance. For such a research interest, many other variables need to be included, from prior domain knowledge to learning activities on the platform.

The investigation of how these variables interact and which emerge as significant predictors appears highly relevant considering the claims made by the field of learning analytics. It needs to be discussed if the identification of "at risk" students is possible based on such data and, if yes, how learners might benefit from early warning systems (Greller and Drachsler, 2012; Scholes, 2016).

# 3 Conceptual framework

With the increasing heterogeneity of first year students' mathematics knowledge, preparatory courses are frequently used by universities to overcome large knowledge differences at the start of tertiary education. These courses aim at decreasing attrition rates and to positively influence study success of students with knowledge gaps in mathematics.

This thesis researched whether participation in a mathematics pre-course impacts first year performance and study success. The research took a particular interest in the effects of course participation on "at risk" students. For practitioners an understanding of successful course design factors and how course design influences learning strategies is considered highly relevant.

The theory of self-regulated learning provided the theoretical framework to analyse the effect of (e)-learning environment, learners' personal attitudes, their use of learning strategies and the interactions between them (Azevedo, 2005). This framework was used to identify the factors that drive successful learning processes of the "at risk" group. By differentiating between relevant and irrelevant factors the yet unanswered theoretical question was addressed which variables are only covariates of prior domain knowledge and which show an effect that is independent of this dominant predictor and might be supported by design.

Figure 7 shows a diagrammatic representation of this approach, with the design of the course and the group of "at risk" students in the focus of interest. The "outcome", study success in engineering, was to be predicted based on first year mathematics performance. The study was to show if and how this variable would be affected by successful pre-course participation, represented by pre-course learning gains. According to the literature, individual pre-conditions related to the self, prior domain knowledge in particular, would be the strongest predictors of first year achievement. According to the framework of self-regulated learning prior domain knowledge was also influential regarding learning behaviour in the pre-course, with students with higher domain knowledge being more able to efficiently make use of learning strategies. The learning environment and its design, as well, could be considered influential. Particularly for the group of “at risk” students it was expected that they would benefit from additional support and guidance. It also could be hypothesised that the design of the course would show an impact on students’ learning behaviour, for example a higher motivation to learn. Considering these interactions the thesis was to investigate which variables would emerge as more relevant for the learning progress of the group of “at risk” students than others. The composition of sub-research questions aimed at identifying these drivers (see next chapter).

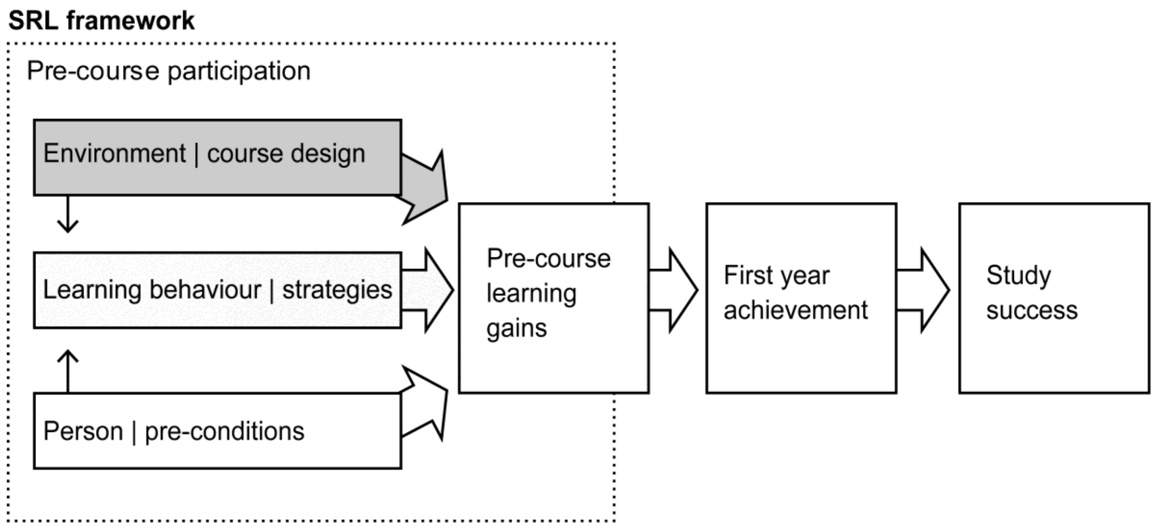



*Figure 7 Conceptual framework: effects of pre-course participation on “at risk” students’ first year performance*

Person- and behaviour-related factors were defined by their presumed relevance for the context of e-learning, mathematics and engineering education. Environmental factors were defined by design elements of the pre-course. Table 5 shows an overview of the variables that were included.

| Dimension | Operationalisation |
|---|---|
| Affect | Attitude towards mathematics (liking, self-confidence, value) |
| Learning strategies | Organisational and time management strategies |
| | Time on task |
| | Task strategies: reading, rehearsal, help seeking |
| Learning environment | Additional (human) guidance and support |
| | System-based guidance and feedback |
| | “Real life” applications of mathematics |

*Table 5 Overview of variables related to the learner and the use of learning strategies in the web-based pre-course in mathematics*

The dimension of affect was included based on the observed relations between students' attitudes and achievement (Robbins *et al.*, 2004; Cretchley, 2008; Chamberlin, 2010; Richardson *et al.*, 2012; Parsons, 2014). It could be presumed that *attitude towards mathematics* would correlate with prior domain knowledge and thus had to be included as a potential covariate. Furthermore, prospective engineering students' motivation to participate in the preparatory course might be increased by a positive attitude towards the subject, or hampered by a negative one (Pintrich, 1999). Thus it was of particular interest what role "at risk" students' attitudes played regarding learning behaviour and pre-course outcomes.

Learning behaviour and students' use of learning strategies were chosen with a particular focus on time management and time on task. The domain of engineering is characterised by a high workload (Meyer and Eley, 1999) and first year students usually don't have the time to recapitulate basic skills once their course of study has begun. In order to adequately prepare for these demands, preparatory courses, as well, are characterised by high workloads. Addressing a heterogeneous group of learners with differing gaps in knowledge they have to cover as much learning contents as possible in a relatively short period of time. It was hypothesised that an effective use of *organisational and time management strategies* to structure the learning contents and to schedule the learning process would positively affect pre-course outcomes, or, reversely, that an ineffective use of learning strategies would result in poorer learning gains (Weinstein *et al.*, 1988b; Carson, 2011; Broadbent and Poon, 2015). Considering the "at risk" group it was hypothesised that they would be less able to make use of such strategies (Artino and Stephens, 2009; Michinov *et al.*, 2011).

In that context it was considered useful to collect measures of students' study time, although the literature suggested only weak positive correlations between *time on task* and achievement in engineering courses (Kember *et al.*, 1996; Kolari *et al.*, 2006) or in web-based environments (Yang *et al.*, 2016). It certainly had to be considered that the quantity of time does not inform on the quality of learning and that there exist some fundamental methodological difficulties to measure study time (Plant *et al.*, 2005; Karjalainen, 2006; Baeten *et al.*, 2010; Bowyer, 2012).

Also related to students' effort was their use of *task strategies*. Task strategies were understood as the types of learning activities that students engage in during the performance phase (Zimmerman and Moylan, 2009). According to the "traditional" literature on self-regulated learning, such strategies not strongly contribute to explaining successful learning processes (Credé and Phillips, 2011) which was somewhat contrasted with research on technology-based learning. In the field of learning analytics it has been shown repeatedly that the type of learning activity does contribute to explaining learning outcomes, with task strategies like answering self-assessments or participating in forums being good predictors of achievement (Morris *et al.*, 2005; Macfadyen and Dawson, 2010; Samson, 2015; Zacharis, 2015; Tempelaar *et al.*, 2015).

The effects of person- and behaviour-related variables on learning gains in the pre-course (and, if applicable, on first year study success) then were related to effects of the e-learning environment. As the environment (design of the course) was the only element that could be manipulated these effects were in the main focus of the conceptual framework.

According to the literature, e-learning environments should provide more guidance and structural support to learners with broad domain-related knowledge gaps, whereas students with an already high level of domain knowledge prefer to study independently (Winters *et al.*, 2008). It thus was assumed that additional guidance, provided by e-tutored and face-to-face courses, would particularly improve the learning gains of "at risk" students (Azevedo and Cromley, 2004; Artino and Stephens, 2009). This presumption was based in social constructivism (Palincsar, 1998; Molenaar and Järvelä, 2014), but was also viable with cognitive psychology, as external structure and guidance were expected to reduce cognitive load (Greene and Azevedo, 2007).

While the guidance provided by the additional courses was provided by human tutors and lecturers, the role of system-based guidance and feedback was to be evaluated, as well. In this study, the focus was on different types of formative e-assessment. One design element was the diagnostic pre-test that aimed at information and calibration (Winne, 2004; Nicol and Macfarlane-Dick, 2006). It was to be analysed how this tool would be used by learners and if it resulted in personal "feedback loops" and evoked self-reflection (Zimmerman and Moylan, 2009).

To evoke self-reflection it also has been suggested to make connections between prior knowledge and other knowledge domains, or to provide "real life" applications of mathematics. Such an approach has been found particularly viable for engineering students, who are likely to prefer the "real life" relevance of mathematics (Kolb and Kolb, 2009; Mazur, 1997) over its abstract beauty (Meyer and Eley, 1999). Making such connections is also viable with the concept of situated cognition that suggests to make learning contents meaningful for the situation of the learner (Lave and Wenger, 1991; Wenger, 1998).

It was of particular interest if "at risk" students would be able to benefit from using these tools, or if the high workload (perceived or objectively true) would result in a higher use of memorisation techniques and "rote" learning (Crawford *et al.*, 1998a; Entwistle and Tait, 1990; Marton *et al.*, 2005a). While such complex interactions could not be observed directly, it was hypothesised that "at risk" students who more frequently engaged in self-monitoring would show higher learning gains and it was also expected that the provision of "real life" examples would result in an increase of motivation and thus result in more learning activities.

Many variables representing learning behaviour could be collected from the e-learning environment, but it needed to be taken into account that quantitative observations of learning behaviour not necessarily inform of the quality of learning. Thus additional information was collected from questionnaires based on existing scales (see section 2.6). Considering the complexity of the model of self-regulation and the sometimes contradicting outcomes of quantitative analyses demonstrated in the review it was considered advisable not to rely on a solely quantitative methodological approach.

Thus all observations made with data collected from the e-learning environment were compared to qualitative outcomes, obtained from interviews with participants. This triangulation helped to undermine or question the quality of results. More importantly, the student perspective was to reveal if the quantitative evaluation had reached saturation or if some important factors had remained unobserved. Thus the final conclusion of this evaluation, making practical suggestion for the design of web-based pre-courses, was based on comprehensive quantitative and qualitative observations.

# 4 Methodology

Before performing the main analysis the learning environment had to be evaluated regarding its overall didactical quality and adequateness; the same applied to the quantitative tools that were to represent the different variables. Thus in a first step a pre-study was conducted that also informed of the practical relevance of the research question for DHBW students.

Based on the course design that was the result of this pre-study and using the revised version of tools the main study was carried out.

The overarching research question

> How does participation in a web-based pre-course in mathematics impact first year tertiary performance of “at risk” students?

was open regarding the outcomes of the study, allowing for an explorative approach. The sub-research questions were used to structure this process:

The pre-study (next section 4.1) was to prepare the setting for the main study, expressed by two sub-research questions that aimed at evaluating the e-learning environment and its adequateness to address prospective DHBW Mannheim students (PQ1) and the quantitative tools that were needed for the main study (PQ2).

The main study (section 4.2) was to show the actual effect of pre-course participation on first year performance of the “at risk” group (MQ1 to MQ3) and to identify the influencing variables alongside the theoretical framework of self-regulated learning (MQ4 to MQ9).

## 4.1 Pre-study sub-research questions

**PQ1 Does the course design provide an adequate e-learning environment?**

This question aimed at providing a learning environment that was undisturbed by content-related, design-related or technical errors. It had to be ruled out, for example, that students were demotivated by poor usability or structure of the learning material. It also could be hypothesised that unexpected interactions with external factors would influence main study outcomes; it thus was evaluated if the e-learning assumptions as formulated in the literature review (section 2.5.1.3) applied to prospective DHBW Mannheim students.

**PQ2 Does the pre-post-test design used for this study adequately represent / measure prior knowledge in mathematics and learning gains in the pre-course?**

The second goal of the pre-study was the development and revision of instruments. Placement tests in mathematics are not mandatory at German universities, therefore no standardised items were available (Blum *et al.*, 2015). As the measurement of learning gains was of particular relevance for this thesis the pre-study was used to develop a reliable and valid pre-post-test and to evaluate its quality. This was to be done with both classical test theory and probabilistic statistical methods (Yen and Fitzpatrick, 2006; Hambleton and Swaminathan, 2010).

## 4.2 Main study sub-research questions

The first two sub-research questions aimed at establishing external validity by reproducing previous findings regarding the relevance of mathematics knowledge for study success in engineering:

**MQ1 Does first year performance in mathematics predict study success at the end of the degree programme?**

In order to ensure that indeed mathematics plays an important role for study success at DHBW Mannheim performance measures of three complete cohorts were analysed. It was hypothesised that study success at the end of the degree programme would correlate with all measures of mathematics performance. The objective was to identify the first year exam Mathematics I as an early indicator of subsequent study success that can serve as dependent variable, avoiding longitudinal analyses.

**MQ2 Do results in the diagnostic pre-test predict first year performance in mathematics?**

By relating pre-test results to first year performance in mathematics this question aimed at reproducing previous findings that placement tests are good predictors of academic achievement in engineering (Zhang *et al.*, 2004; Henn and Polaczek, 2007; Ehrenberg, 2010; Faulkner *et al.*, 2010; Carr *et al.*, 2013; Abel and Weber, 2014; Greefrath *et al.*, 2016). It was hypothesised that pre-test results would not only correlate with first year mathematics performance (which was relevant for the study design) but with other collected measures of prior and subsequent performance, as well, thus establishing external validity. This investigation therefore was to show which of the collected potential predictors (gender, age, type of school, secondary performance) would play a significant role in the overall model. The results obtained from these analyses then were used to identify an "at risk" group at DHBW Mannheim.

After having confirmed the presumption that gaps in basic mathematics knowledge put a risk on first year students' chances to pass their first mathematics exam it was investigated if pre-course participation reduced this risk.

**MQ3 Does participation in the pre-course improve first year performance in mathematics?**

The literature suggests only weak effects of pre-courses compared to the dominant influence of prior domain knowledge (Ballard and Johnson, 2004; Bettinger and Long, 2009; Lagerlöf and Seltzer, 2009; Di Pietro, 2012; Greefrath *et al.*, 2016; Calcagno and Long, 2008). For this study it was of particular interest if the “at risk” group overproportionally benefitted from pre-course participation. It thus was hypothesised that pre-course learning gains (represented by pre-post-test difference) could be related to an increase in first year performance in mathematics and that this increase was higher for the “at risk” group.

The sub-research questions SRQ4 to SRQ7 question zoomed in on the different elements of the learning process and their influence on pre-course learning outcomes and, if applicable, first year performance in mathematics. All of these questions were focused on the group of “at risk” students.

**MQ4 How does attitude towards mathematics impact learning gains of the “at risk” group?**

Affective variables are considered influential regarding students’ motivation to learn (Pintrich, 1999); furthermore, attitude and motivation have been found to correlate with academic achievement (Robbins *et al.*, 2004; Richardson *et al.*, 2012). As mathematics is not the prior study interest of engineering students negative attitudes could be considered an obstacle for successful pre-course participation (Meyer and Eley, 1999). Thus different dimensions of attitude (liking mathematics, self-confidence in mathematics, and value mathematics) were included as a person-related covariate (Kadijevich, 2006). It was hypothesised that attitude towards mathematics would be positively correlated with prior domain knowledge or with pre-course learning gains.

**MQ5 How does the use of time management and organisational strategies impact learning gains of the "at risk" group?**

Evaluations of students' learning strategy use have shown that, compared to other strategies, time management and organisation have a positive impact on achievement (Weinstein *et al.*, 1988b; Entwistle and McCune, 2004; Carson, 2011; Credé and Phillips, 2011; Richardson *et al.*, 2012; Broadbent and Poon, 2015). Particularly students with poor domain knowledge seem to lack the ability to structure and plan their learning process and make an adequate use of their time. Thus different dimensions of organisational strategies (preparing a schedule, studying in a quiet environment) were included as learning-behaviour-related covariate. It was hypothesised that the use of time management and organisational strategies would be positively correlated with prior domain knowledge or with pre-course learning gains.

**MQ6 How does time on task impact learning gains of the "at risk" group?**

While not a learning strategy, time on task represents the effort students invest into the learning process (Kember, 2004; Bowyer, 2012). Although research in education suggests only weak positive correlations between time on task and learning outcomes (Wagner and Spiel, 2002; Plant *et al.*, 2005; Macfadyen and Dawson, 2010) it was considered relevant for the web-based pre-course. Students with broad knowledge gaps were expected to need more time to close these gaps; at the same time this group of learners has been found to be more inclined to procrastinate (Artino and Stephens, 2009; Michinov *et al.*, 2011). Thus different dimensions of time on task (self-reported study time, number of accessed learning modules) were included as learning-behaviour-related covariates. It was hypothesised that the amount of time students put into their learning would be positively correlated with pre-course learning gains.

**MQ7 How does the use of task strategies and help seeking impact learning gains of the "at risk" group?**

Regarding the use of task strategies like making self-explanations, reading texts, or rehearsal, the literature is not consistent. When operationalised by inventories like MSLQ or LASSI their correlation with performance seems to be poor (Credé and Phillips, 2011). Studies comparing the effects of tracking data, on the other hand, found that rehearsal, or doing self-tests, was a good predictor of course achievement (Morris *et al.*, 2005; Macfadyen and Dawson, 2010; Samson, 2015; Zacharis, 2015; Tempelaar *et al.*, 2015). For this study it appeared relevant to analyse how students made use of the e-learning environment. Thus different dimensions of task strategy use (number of learning module page views, number of self-tests) were included as learning-behaviour-related covariates. It was hypothesised that the number of learning activities or online interactions like forum posts and help seeking would be positively correlated with pre-course learning gains.

**MQ8 How does the chosen course type impact learning gains of the "at risk" group?**

One central design variation in the course design were different forms of additional support. Previous research has shown that inexperienced learners with low levels of self-regulation benefit more from guided and structured course designs (Azevedo and Cromley, 2004; Artino and Stephens, 2009). As self-regulation also correlates with domain knowledge it was hypothesised that "at risk" students who participated in an additional face-to-face or e-tutored course would show higher learning gains than "at risk" students who studied alone.

After having identified the variables that most strongly contributed to explaining learning gains of the "at risk group" it needed to be analysed if and how they interacted with each other. The final sub-research question then explored if and how the course design had been successful in supporting self-regulated learning processes.

**MQ9 How does system-based guidance impact the "at risk" group's use of learning strategies and self-reflection?**

With Winne (2004) and Nicol and Macfarlane-Dick (2006) it was hypothesised that system-based guidance and feedback, as provided by the diagnostic pre-test (and the corresponding post-test) would raise students' awareness for the importance of the basic skills in mathematics and thus have an activating effect, but also help them to structure the learning process and evoke reflection about its goals and outcomes (Zimmerman and Moylan, 2009).

Furthermore, it was to be explored if the observations made in the pre-study (section 5.2.6) that students demanded more "real life" examples showing the application of mathematics, could be confirmed and related to learning behaviour.

**MQ9a How does the provision of mathematical problems in a "real life" context impact the "at risk" group's use of learning strategies and self-reflection?**

Referring to previous research that had shown positive effects on the learning experience in engineering education (Kendall Brown *et al.*, 2009; Preißler *et al.*, 2010; Young *et al.*, 2011; Härterich *et al.*, 2012; Rylands *et al.*, 2013; Rooch *et al.*, 2014) it was to be explored if such an approach was transferable to the context of a pre-course in mathematics. It was hypothesised that "at risk" students would prefer to study with mathematical problems related to daily life, technology, or engineering.

## 4.3 Methodological approach

For the evaluation a methodological framework was needed that allowed for an interactive and iterative approach to data collection. The following three research approaches were considered appropriate, action-based, design-based, and case-based research.

### 4.3.1 Action-based research

Action research projects are driven by practical outcomes, for example the change management process of a company or the implementation of innovative teaching approaches at a tertiary institution (Olds *et al.*, 2012). Typical for action research are projects that investigate different stakeholders' views on a situation, allowing a "multiple understanding of complex social systems" (Riel, 2016). The inclusion of all participants into the process of knowledge generation also ensures higher levels of commitment and acceptance (Levin and Greenwood, 2008) and helps to identify actions that support change (Krockover *et al.*, 2002; Stieha *et al.*, 2016). Action research projects are characterised by iterative research designs, consisting of several cycles of diagnosis, planning, action taking, and evaluation (Davison *et al.*, 2004) based on qualitative or mixed methods designs.

### 4.3.2 Design-based research

Similar to action research, design-based research approaches are characterised by repeated evaluations, or an "approach of progressive refinement" (Collins *et al.*, 2004, p.18) but with a focus on the design of activities or artefacts (March and Smith, 1995). Design research is a method to systematically test, revise and study "engineered" learning environments (Cobb *et al.*, 2003, p. 9). One important characteristic is the demand to provide generalisation of a relevant problem and describe how this problem was solved by developing artefacts and by implementing them in a system or organisation (March and Storey, 2008). Design-based approaches have been used in many (e-)learning contexts, for example prototype development for corporate learning programmes (Wang *et al.*, 2011) or analysis of the influence of collaborative learning on student motivation (Jones *et al.*, 2015;

Guloy *et al.*, 2017). As action research, design-based research is open to many different forms of data collection, from interviews with participants or experts to evaluation of log files, course diaries, or questionnaires (Hrastinski *et al.*, 2010; Jahnke, 2010).

### 4.3.3 Case-based research

A third alternative to addressing the research interest was using a case-based approach. As stated by Yin, case studies are an "integral part of evaluation research" (Yin, 2003, p. xi) but have been associated rather with evaluation of process than evaluation of outcomes.

Examples for case studies can be found in engineering education (Winkelman, 2009; Li, 2015) as well as in e-learning (McNaught *et al.*, 2012; McEachron *et al.*, 2012; Hutchings *et al.*, 2013), or in engineering e-learning education (Francis and Shannon, 2013) with an overall broad variance in scope and interest. Granić and Ćukušić (2011), for example, conducted a case study comparing different methods of usability evaluation on a cross-institutional platform, comprising a broad variance of quantitative and qualitative data sources. Francis and Shannon (2013), by comparison, conducted a strictly quantitative evaluation of the implementation of a blended learning design at a technical faculty. Finally, Wedelin *et al.* (2015) reported from a qualitative case study exploring engineering students' mathematical modelling and problem solving skills which was used to make suggestions for the improvement of the mathematics course.

### 4.3.4 Summary

Summarising, action research and design-based research share many characteristics that seemed relevant for this study. Both approaches are iterative, explorative, and not restricted to either quantitative or qualitative methods, thus “in the camp of applied research.” (Anderson and Shattuck, 2012, p. 17). Cole *et al.* (2005) found that the defining qualities of both AR and DBR could be related to the common “meta-paradigm” of pragmatism. Finally, both approaches could be linked to evaluation research; action research in responsive evaluation as introduced by Stake (1975) and design research in formative evaluation (Richey *et al.* (2004)).

The biggest difference between action research and evaluation is that the former adds the element of change to the research purpose (Stringer, 2007) – a demand only partially met by this thesis. It certainly was to be expected that the outcomes of this study would result in an improved pre-course programme, but the participatory element appeared too weak to justify an AR approach.

Design-based research, as well, has been found closely related to formative evaluation. Both have in common iterative cycles of development, enactment, and study. They differ, though, “in the ways context and interventions are problematized” (Design-Based Research Collective, 2003, p. 7) and in their demand to generate hypotheses. According to Cobb *et al.*, DBR projects should not only deliver an abstract theory but “detailed guidance in organizing instruction” (Cobb *et al.*, 2003, p. 10). As stated above, the overall goal of this study included practical suggestions for the design of pre-courses in mathematics; however, these suggestions did not involve the development of a new theory but rather a prioritisation and clarification of existing approaches in a specific context.

Both demands, generating change as in AR, and developing theory as in DBR, go beyond the interest of this thesis. While being explorative it was strongly attached to existing theories and in these limitations sought to differentiate between meaningful and less meaningful factors in the context of a mathematics pre-course at one particular university. It therefore seemed most appropriate to choose a case-based approach. Some of the observations made at this university are likely to be transferable to other technical faculties, particularly if existing knowledge as described in the literature review could be reproduced with the collected data. As stated by Greene *et al.* (2001):

> "Evaluation should serve primarily to contribute to conceptual and practical knowledge regarding how to best address our social problems. Evaluators should concentrate on understanding the meaningfulness and effectiveness of a given program design and implementation in a given context, toward better understanding of that programmatic response to that social problem." (Greene *et al.*, 2001, p. 29)

## 4.4 Rationale for a mixed methods research approach

The research interest of this thesis was to explore and understand how participation in a web-based mathematics pre-course could support DHBW Mannheim engineering students' transition to tertiary education.

The study thus aimed at accomplishing different goals: First, providing evidence that the "mathematics problem" was relevant at DHBW Mannheim's technical faculty, thus reproducing (or contradicting) relations observed in the literature. Second, the effect of pre-course participation on these relations was to be evaluated. Third, it was to be explored which variables most strongly contributed to explaining pre-course learning gains or first year study success.

All three goals refer to the argumentation that first year students need additional mathematics support and that extra-curricular mathematics tutoring is a potential remedy. A lot of financial funding goes into the implementation of pre-courses in mathematics; and usually these projects are based on quantitative information, like increasing failure or withdrawal rates. It therefore seemed appropriate to follow a quantitative approach for this part of the investigation. At the same time it had to be acknowledged that the influence of pre-course participation on study success in the "complex" and "shifting" context of open web-based programmes would be difficult to quantify (Price and Oliver, 2007, p. 17). Thus a triangulation with qualitative data was needed that supported or contrasted the quantitative observations and thus helped to identify interferences and yet unobserved factors.

Even more importantly, the student experience was to explain the outcomes of the explorative analysis and to give a more detailed exploration of how learners made use of the e-learning environment and what motivated their behaviour.

This study is therefore situated at the tension between the two demands of (a) "measuring" the effectiveness of a course and of (b) accounting for the complexity of the learning process. It's starting point and theoretical orientation is located between the two epistemological positions of (post-)positivism and interpretivism (Crotty, 1998).

According to the “two-paradigm typology” (Hammersley, 2012) interpretative views are located at one end of an imaginary scale and positivist views at the other. In this dichotomy, interpretative and constructivist views aim to understand and reconstruct meaning, accepting “multiple knowledges” (Guba and Lincoln, 1994, p. 113). As stated by Denzin, “in the social sciences there is only interpretation. Nothing speaks for itself” (Denzin, 1994, p. 500). By comparison, positivist and post-positivist views seek to describe, explain, predict and control observed phenomena (Guba and Lincoln, 1994, p. 113).

In educational research, both paradigms have a tradition and a justification. While it is undisputed that education is a social activity and cannot be isolated from the environment in which it takes place, research on education also has a (post-) positivist side represented by cognitive research, educational psychology, and psychometrics. Both strands have traditionally been related to differing methodological approaches, with qualitative research at the interpretivist and quantitative research at the positivist end of the scale. Such dichotomies have been useful to emphasise differences (Lather, 2006), but also are ambiguous as they suggest a separation between disciplines. As Gerring argued: “the virtues of the experimental method extend to all methods, in varying degrees, and it is these degrees that ought to occupy the attention of practitioners and methodologists” (Gerring, 2009, p. 12). Accordingly, quantitative methods have also been considered viable in interpretivist research approaches (Case and Light, 2011).

Greene suggested to differentiate between four major approaches to programme evaluation (Greene, 1994, p. 532):

1. *Focus on effectiveness and cost efficiency* of a programme, the “historically dominant tradition in program evaluation” (Greene, 1994, p. 532), usually addressed from a post-positivist view preferring quantitative experimental or quasi-experimental approaches and causal modelling
2. *Focus on practicality,* acknowledging the challenges of experimental designs, weighing single aspects of the programme against each other and taking a pragmatist philosophical stance, usually in mixed methods designs (Patton, 1990)

3 *Focus on value orientation and contextualised understanding* acknowledges the perspectives of different stakeholders. Its underlying framework is interpretative, employing quantitative or qualitative methods, often in combination with a case study methodological orientation (Greene, 1994, p. 533)
4 *Focus on social phenomena* puts the evaluation in a larger a societal or political perspective, evaluating the programme from a critical philosophical framework, based on either quantitative, qualitative, or mixed designs (Guba and Lincoln, 1989)

Some aspects of this thesis suggested to take the traditional view on evaluation and its demand to demonstrate efficiency but, considering the multi-faceted nature of the context, it was also considered important to include the student perspective and take an interpretative view. Based on these considerations a focus on practicality as in (2) was adopted that also acknowledged the relevance of the context as suggested in (3). The evaluation was to aim at measurement and meaning in terms of empirical findings.

*Mixed methods case study design*

According to Bromley (1986), case-based research in education aims at investigating complex systems and should observe the different structures and functions that contribute to their operation and performance. It has been argued that mixed methods approaches more appropriately account for the complexity of a situation as they allow to combine different types of data, from demographic to test scores to interviews, and to analyse them either quantitatively or qualitatively. At the same time, mixed designs have been criticised for being eclectic (Tashakkori and Teddlie, 2010, p.5) or for lacking scientific rigour (Gorard, 2007; Collins, 2012).

In this study the point of view is taken that quantitative and qualitative approaches to data collection are not so much representatives of opposed research philosophies but different forms of collecting evidence. While it is important to acknowledge the historical backgrounds of the dichotomy (Schwandt, 2006) it may be no longer productive to maintain it. As suggested by Gherardi and Turner (1987), “hard” facts only show a small excerpt of the “reality” and can be as vague and ambiguous as the “soft” results of qualitative investigations. It is thus no contradiction to look at quantitative outcomes from a constructivist perspective (Koro-Ljungberg and Douglas, 2008).

It has been stated that following a mixed methods approach could be considered a “third perspective” (Coe, 2017, p. 8) and thus a philosophical approach in its own right. Philosophical pragmatism goes back to the work of Peirce, and later Dewey (Hammersley, 2012). In this thesis pragmatism is not so much used in the sense of an epistemological stance but as an “umbrella foundation” (Creswell and Plano Clark, 2011, p. 101) and a way to approaching a research problem (Morgan, 2007) and to choosing a study design (Johnson and Onwuegbuzie, 2004).

In a case study the aim is to analyse and understand an issue or problem using the case as an illustration (Creswell, 2013). The context of this case study, the implementation of a pre-course at one particular university, was explored from different perspectives and different data sources. The implementation of the web-based pre-course at DHBW Mannheim could be considered as a “holistic single case” (Yin, 2009). Different sources of information provided different perspectives on this case. The design thus was a collective case study, combining the large-scale quantitative findings with findings from individual qualitative interviews.

For this study a sequential design was chosen. Both pre-study and main study used a combination of quantitative and qualitative investigations and both studies and strands informed each other.

In the pre-study (see chapter 5.2) triangulation of quantitative with qualitative data was used to evaluate the learning material and how it was presented in the pre-course and to shape the educational design in the process. Results from early phases thus informed the next phases and helped preventing that important issues were overseen (Johnson and Onwuegbuzie, 2004). The goal of this approach was “to minimize study biases that derive from inherent design weaknesses” (Caracelli and Greene, 1997, p. 23).

The main study (chapter 5.3) was based on quantitative analyses that were re-interpreted from the learners' perspective, thus explaining, refining, or contrasting previous interpretations and conclusions (McCarthy and Wright, 2004). By doing that, the study aimed at describing causal relations between different sets of variables as well as deviations from the general model. It could be expected that some results would not be converging or even conflict in results (Greene *et al.*, 2001) and these conflicts were to be highlighted by using multiple data sources.

# 5 The studies

Figure 8 provides an overview of the design of the studies. The pre-study that prepared the setting for the main study was carried out from 2011 to 2013. The quantitative strand of the main study was carried out with the data collected from the 2014 cohort and repeated in 2015 and 2016. The final qualitative investigation was conducted with students who participated in the course in 2016. In the following sections the different phases and the process of data collection will be explained in more detail.

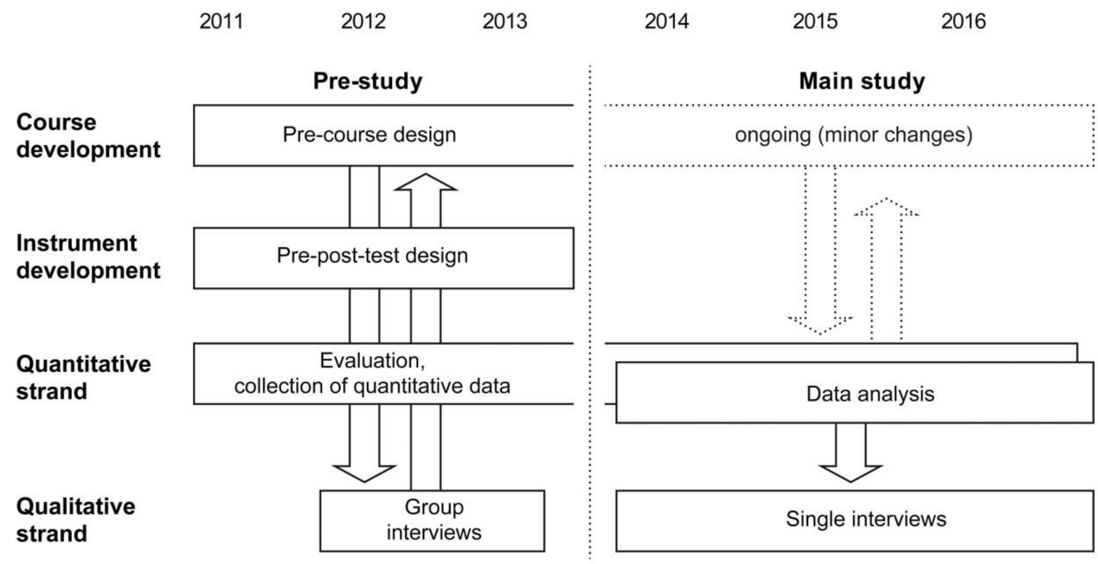



*Figure 8 Research design and data collection pre-study and main study*

## 5.1 Descriptive analyses

In this section descriptive analyses of the six participating cohorts are summarised. If applicable, significant differences within or between groups are reported.

The number of first year students at DHBW Mannheim was relatively stable, with a significant increase in 2012 due to an abridgement of secondary school duration from nine to eight years in several German federal states. With a third of the student body, Mechanical engineering was the largest course at DHBW Mannheim' technical faculty, whereas Industrial engineering was the smallest (14% of the student body).

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Computer science | 116 | 126 | 122 | 117 | 120 | 120 |
| Industrial engineering | 85 | 102 | 101 | 101 | 109 | 103 |
| Mechatronics | 152 | 169 | 141 | 120 | 125 | 139 |
| Electrical engineering | 132 | 178 | 128 | 135 | 140 | 160 |
| Mechanical engineering | 230 | 253 | 224 | 235 | 213 | 245 |
| Total | 715 | 828 | 716 | 708 | 707 | 767 |

*Table 6 First year students per degree programme 2011 to 2016*

On average, 79% of all first year engineering students registered on the web-based platform and participated in the diagnostic pre-test. These students were ascribed to the group of pre-course participants (regardless of their subsequent learning activities). Nearly all first year students (between 98% and 99%) participated in the post-test. Students who participated in the post-test only were ascribed to the group of non-participants.

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Pre-course participation | 209 | 186 | 119 | 105 | 156 | 171 |
| No pre-course participation | 506 | 642 | 597 | 603 | 551 | 596 |
| Total | 715 | 828 | 716 | 708 | 707 | 767 |

*Table 7Number of pre-course participants per year*

### *Gender*

With an average rate of 14%, the number of female students at DHBW Mannheim was representative for engineering degree programmes in Germany (cf. Autorengruppe Bildungsberichterstattung, 2012). There was a non-significant increase of female students from 12% in 2011 to 16% in 2016; in 2014 the ratio was 13%.

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| male | 639 | 719 | 619 | 615 | 598 | 641 |
| female | 76 | 109 | 97 | 93 | 109 | 126 |
| total | 715 | 828 | 716 | 708 | 707 | 767 |

*Table 8 Number of male / female first year engineering students 2011 to 2016*

There were interactions between gender and variables related to educational background. Female students more often graduated from a “traditional” secondary school (*Gymnasium*) (2014: 86% versus 72% of male students) and also had higher secondary school GPAs than male students, accounting for 0.2 grades (on a scale from 1 to 4). These differences were significant, suggesting that the starting position of the much smaller group of female students’ was slightly higher.

*Age and gap between secondary and tertiary education*

Due to the abridgement of secondary school duration from nine to eight years in some (but not all) federal states in 2012 there was a decrease in average age from 20.4 in 2011 to 20.2 in 2014. The differences in age between cohorts, however, were not significant. The majority of first year students was 19 years old, suggesting some extreme outlying values. A higher age correlated with the gap between secondary and tertiary education; both variables were also related to type of secondary education. Traditional students (*Gymnasium*) were younger than students from secondary schools with a focus on technical or economic subjects (plus 0.7 years in 2014) or from vocational schools (plus 2.4 years).

*Federal State*

While not in the focus of this study the federal state needed to be observed, as secondary school systems differ slightly throughout Germany. Not surprisingly the largest group of students stemmed from Baden-Wuerttemberg (25%), followed by Rhineland-Palatinate (21%) and Hesse (18%) which are close to the Mannheim area. The fourth largest group stemmed from North Rhine-Westphalia (11%), and nine per cent stemmed from Bavaria. This ratio remained stable throughout the study. An analysis of educational backgrounds suggested that students from Baden-Wuerttemberg less often had attended traditional schools than students in the four other federal states (62% versus 77%). This difference was significant for all cohorts but 2012. The best secondary school GPAs were obtained by students from Bavaria and North Rhine-Westphalia, suggesting that high performing students were more likely to leave their hometowns to take up a degree programme in Mannheim. It could be hypothesised that mainly large partner companies in the industrial Southwest of Germany were able to attract these students.

*Type of secondary school*

The largest group (74%) were traditional students who had attended a *Gymnasium* and obtained a graduation that allowed progression to all German universities (*Abitur*). As stated above, this group was also the youngest, with an average age across cohorts of 19.8. The second largest group were students who graduated from a subject-related secondary school (*Berufliches Gymnasium*, focused on technical subjects) (14%). 12% had a leaving certificate from a vocational school that allowed studying at universities of applied sciences only (*Fachhochschulreife*). These distributions were stable throughout the study.

*School grades in mathematics*

Secondary school grades in mathematics were not available from the administrative data base and thus collected from the web-based questionnaire that was administered together with the diagnostic pre-test. 51% of the students stated they had obtained "good" grades in mathematics, and 26% had been "very good" in mathematics. The remaining 23% had either "medium" grades (19%) or "poor" grades (4%) in mathematics. When comparing types of secondary school, students from traditional schools more often had obtained "very good" grades whereas students from vocational schools were more likely to have "medium" or "poor" grades. While these differences were not significant it seemed a noticeable observation, suggesting that the gap between traditional and non-traditional first year students was increased by these interactions.

*Secondary GPA*

The average secondary GPA, measured on a scale from 1 (very good) to 4 (poor), was 2.2. It did not significantly change throughout the study. The cohort with the best secondary GPA was 2016 (2.148), the cohort with the poorest was 2014 (2.198). The differences between cohorts, though, were not statistically significant.

*Summary*

Concluding, the descriptive analyses raised no concerns that would have suggested an exclusion or correction of data. However, there were some interactions between demographic and educational background that had to be considered when interpreting the quantitative analyses. Traditional students were not only the largest group, these students were also younger than the rest of the sample and in this group the rate of female students was higher. It also needed to be considered that in the course of the Bologna process there had been an abridgement of secondary education. In 2012 students from the nine- and eight-year long secondary school graduated together, resulting in larger numbers of students and an even more heterogeneous student body in that year.

## 5.2 Pre-study

The pre-study was used to develop the course programme and the quantitative tools (pre-post-test design and questionnaires) and it also was used to refine the sub-research questions. The pre-study outcomes were based on quantitative and qualitative analyses and both strands delivered information (Greene *et al.*, 2001). The author of this thesis was part of the development team and responsible for the design of the e-learning environment, the structure of the course, and the implementation of interactive elements like test feedback, animations, or interactive content.

The first goal of the pre-study was to evaluate and successively improve the design of the course and minimise the risk that conceptual or methodological flaws would influence main study outcomes (PQ1: Does the course design provide an adequate e-learning environment?). It therefore seemed appropriate to triangulate different data sources (Kerres and Witt, 2004). The outcomes of this analysis are reported together with a description of the final design of the pre-course (section 5.2.4).

The second goal of the pre-study was the development and revision of instruments; the diagnostic pre-test and a corresponding post-test were fundamental for all quantitative investigations performed in the main study (PQ2: Does the pre-post-test design used for this study adequately represent / measure prior knowledge in mathematics and learning gains in the pre-course?). This part of the study was also used as a “laboratory”, exploring methodological aspects of the study (Robson, 2011). These are reported in section 5.2.5.

### 5.2.1 Study design and data collection

Throughout the pre-study an evaluation questionnaire was administered to pre-course participants, covering usability issues, technical problems, students’ perception of test difficulty and their satisfaction with the programme (see Table 9). This information was enriched by group interviews with pre-course participants.

| Variable | Source |
|---|---|
| Educational and demographic background: | survey / administrative data base |
| Gender, age, gap between secondary and tertiary education, federal state, type of secondary school, mathematics grades at school | 7 items |
| Evaluation questionnaire: | survey |
| Satisfaction with technical performance, usability, difficulty level | 6 closed questions, 4 open questions |
| Learning activities online / offline | 5 closed questions |
| Study time | 2 closed questions |
| Prior knowledge in mathematics | pre-test score in % |
| Pre-course learning gains | pre-post-test difference |

*Table 9 Overview of quantitative variables pre-study*

### *Group interviews*

In this early part of the study the major interest was to pre-test the educational setting, the focus groups thus were used in the sense of Morgan (1988) (or Merton, 1987) as a pre-study. In order to avoid that important factors were overseen, as much and as diverse information as possible had to be collected. Group interviews have been found helpful when the research interest revolves around a specific topic, using the interviewees as experts (Hopf, 2004; Watts and Ebbutt, 1987). The sampling aimed at "maximum variation" (Patton, 1990, p. 172); participants were chosen from the five different course programmes, had different educational backgrounds (traditional and non-traditional) and knowledge levels.

The group interviews lasted between 30 and 50 minutes. The interviewer used a guideline to structure the conversation but also allowed to depart from these questions (see Appendix E). The interviews were digitally recorded and transcribed verbatim. The transcripts were roughly coded by examining the raw data and identifying recurring statements, using only the first step of qualitative content analysis (Mayring, 2000 and 2014). The resulting categories were used to revise the learning material. Issues that emerged as relevant for the research interest were cross-checked with the hypotheses formulated in the sub-research questions.

### 5.2.2 Sample

The pre-study was based on the data collected from three cohorts of first-year students (2011-2013). Each year between 70% and 80% of all first year engineering students took both tests (diagnostic pre-test and post-test). For the analysis these students were ascribed to the group of "pre-course participants", regardless of their level of learning activity. The evaluation questionnaire was attached to the post-test, thus was answered by the majority of pre-course participants.

In 2012 three group interviews were conducted with pre-course participants from the degree programmes industrial engineering ($n$ = 7), electrical engineering ($n$ = 4), and mechanical engineering ($n$ = 2). In 2013, two further interviews were carried out with students from industrial engineering ($n$ = 2), electrical engineering ($n$ = 2), and mechanical engineering ($n$ = 1), computer science ($n$ = 2), and mechatronics ($n$ = 4).

| Cohort | 2011 | 2012 | 2013 | (2014)* |
|---|---|---|---|---|
| First year students | 724 | 845 | 738 | 722 |
| Pre-course participants (pre-test + post-test) | 506 | 642 | 597 | 603 |
| Questionnaire I: demographic + attitude scales | 501 | 641 | 594 | |
| Questionnaire II: evaluation + learning strat. scales | 503 | 633 | 577 | |
| First year students | 715 | 828 | 716 | 708 |
| Post-test only participants | 209 | 186 | 119 | 105 |
| Group interview participants | | 13 | 11 | |

*main study, used for repetition of pre-post-test analysis

*Table 10 Sample overview pre-study*

### 5.2.3 Ethical considerations

For the preparation of the pre-study the German data privacy laws on federal and state level as well as ethical considerations were accounted for. Suggestions for the anonymisation of quantitative and qualitative data were followed, e.g. usage of replacements and pseudonyms or removal of direct and indirect identifiers (UK Data Service, 2013; Gebel *et al.*, 2015). The university's data privacy official gave ethical approval. Pre-course participants were informed on the purpose of the study and agreed that their learner data were collected, anonymised, and evaluated. Students aged under 18 provided a parental consent. Tests and questionnaires were completed voluntarily and anonymously. Interview participants were informed of the research interests and that their statements would be recorded. They agreed that some statements would be published in an anomymised way that would prohibit disclosure of their identity (Walford, 2005; Kelly, 2009).

### 5.2.4 Results: Course design

In this chapter the design and revision process of the pre-course in mathematics is summarised. Its goal was to develop a course design that "works", so that design-related issues (usability, adequateness of learning contents regarding difficulty level, wording, or curriculum) would not influence main study outcomes. Throughout the pre-study many modifications were made but not all appeared relevant for this report. For example, changes in learning module texts, graphs, and animations were considered as too specific. For reasons of clarity the different steps of course development were omitted, as well. Instead, the pre-course in its final version that was implemented in the main study is presented in the following sections. Amendments and design changes are only mentioned when considered relevant.

Figure 9 shows an overview of the different elements of the pre-course. Each year the learning environment could be accessed from June on. Pre-course participation was not mandatory and access to the web-based learning material was free of charge. Via the university's homepage and mailing lists students were encouraged to enrol in the course and (at least) test their basic skills in mathematics by taking the diagnostic pre-test. Based on students' results in this test the diagnostic feedback recommended a list of learning modules. Students could work through these modules independently but they also had the possibility to participate in additional face-to-face (added in 2012) or e-tutored courses (added in 2014). Finally, a post-test was taken at the university's computer labs during induction week. Students who still performed poorly (below 60%) were advised to attend a first year tutorial.

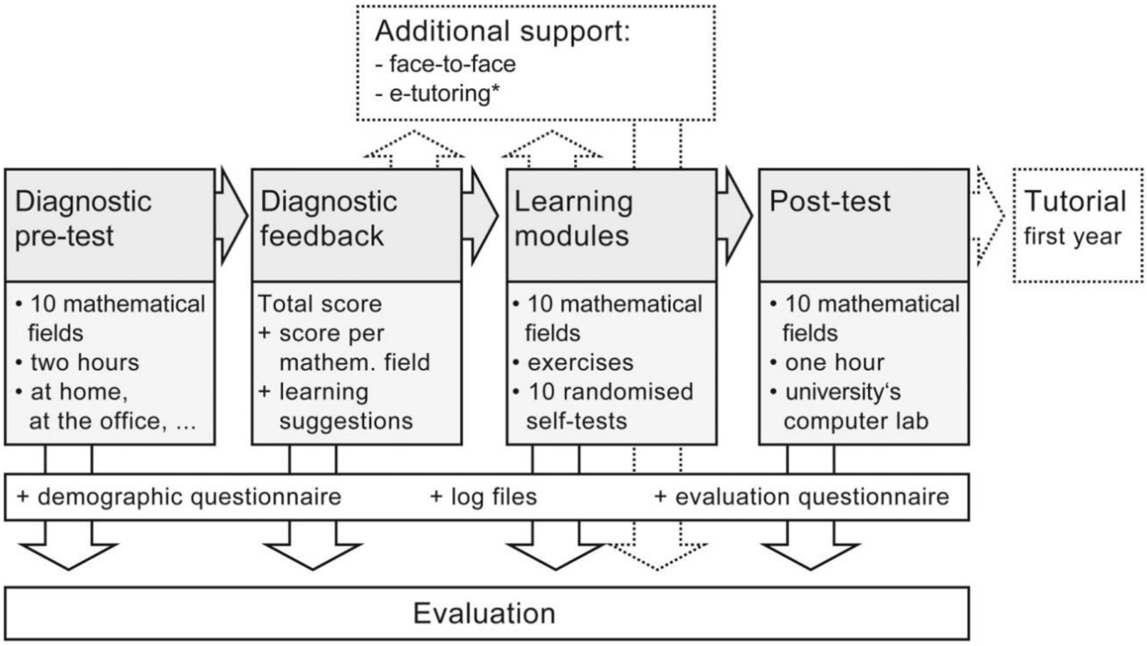



*Figure 9 Overview of the pre-course design (*the face-to-face courses were added in 2012, the e-tutoring courses were added in 2014)*

Before enrolment a privacy statement informed students that their results and user data would be treated confidentially and anonymised for evaluative purposes. The technical platform was an installation of the free LMS (learning management system) Moodle. For the diagnostic tests standard Moodle quizzes were employed, for evaluation the questionnaire plug-in, and for learning content the lesson module. Some of the randomised test items used the plug-in STACK (Sangwin, 2013).

### 5.2.4.1 *Diagnostic pre-test*

The two hour diagnostic self-test covered ten mathematical fields (see next section on curriculum) and each topic was addressed by a set of 6 to 10 items. Each item was designed to address mainly one mathematical skill (for example "solving a quadratic equation" related to the mathematical field (2) Equations). Two item types were chosen for this design, numeric entry and MC (multiple-choice). The advantage of these simple item types was that, compared to more complex technical solutions like STACK (Sangwin, 2013), the input of results was technically easy and thus no hurdle for inexperienced e-learners. The test also provided a simple online calculator (https://web2.0calc.com/widgets).

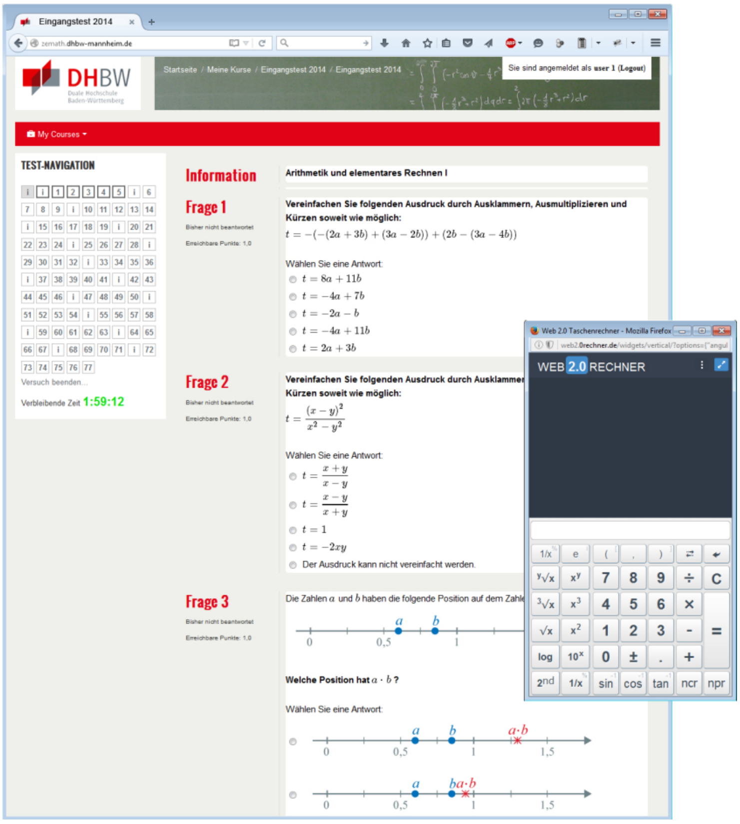


*Figure 10 Screenshot of the diagnostic pre-test (three multiple choice items plus web-based calculator widget)*

The first evaluation had shown that the test's difficulty level was perceived as rather high by students and that many participants were unable to complete the test in the given time. Nearly 50% referred to this test as "difficult" (2011: $n$ = 216; 2012: $n$ = 281) or "very difficult" (2011: $n$ = 18; 2012: $n$ = 49). Accordingly, only one per cent described the test as "easy" or "very easy" (2011: $n$ = 6; 2012: $n$ = 3) and the average mean score was relatively poor in both years (2011: 49.4, $n$ = 506; 2012: 43.5, $n$ = 642).

After the revision (see section 5.2.5.4) the test results were not considerably higher; however the student feedback was more consistent and in its final version in 2014, 36% described the difficulty level as "adequate" and 30% considered it as "difficult" ("very difficult": 3%).

#### 5.2.4.2 Course curriculum

The learning material covered the mathematical curriculum as taught at German secondary schools. The syllabus of the federal state of Baden-Wuerttemberg as well as the final report of the working group (cosh cooperation schule:hochschule, 2014) were used as a reference. The cosh selection is in alignment with the “Core Zero” mathematics curriculum as suggested by the European Society for Engineering Education, SEFI (SEFI mathematics working group, 2013). All learning contents were discussed in detail with two DHBW Mannheim mathematics lecturers and the resulting list was used as a framework for the course syllabus. Note that the SEFI curriculum also suggests to include statistics and probability, an issue that was not (yet) adopted.

(1) Arithmetic
(2) Equations
(3) Powers, roots, and logarithms
(4) Functions
(5) Geometry
(6) Trigonometry
(7) Logic
(8) Real numbers
(9) Vectors and linear algebra
(10) Continuous functions and limits

It had been hypothesised that the first evaluations would suggest some knowledge areas to be more critical than others, which would then have helped to restructure and prioritise the quite comprehensive syllabus. This was not the case; the pre-study analyses indicated knowledge deficits in all topics, with highly heterogeneous basic skills, e.g. working with fractions, applying power and logarithm rules, or the identification of basic functions (Crowther *et al.*, 1997; Lawson, 2000; Faulkner *et al.*, 2010). Considerable knowledge gaps were found in trigonometry and logic, and broad gaps in vectors (Knospe, 2011; Greefrath *et al.*, 2014). (*Note:* during the last school reforms in Germany *(10) Continuous functions and limits* was completely removed from several secondary syllabi and thus was also removed from the pre-post-test design in 2016).

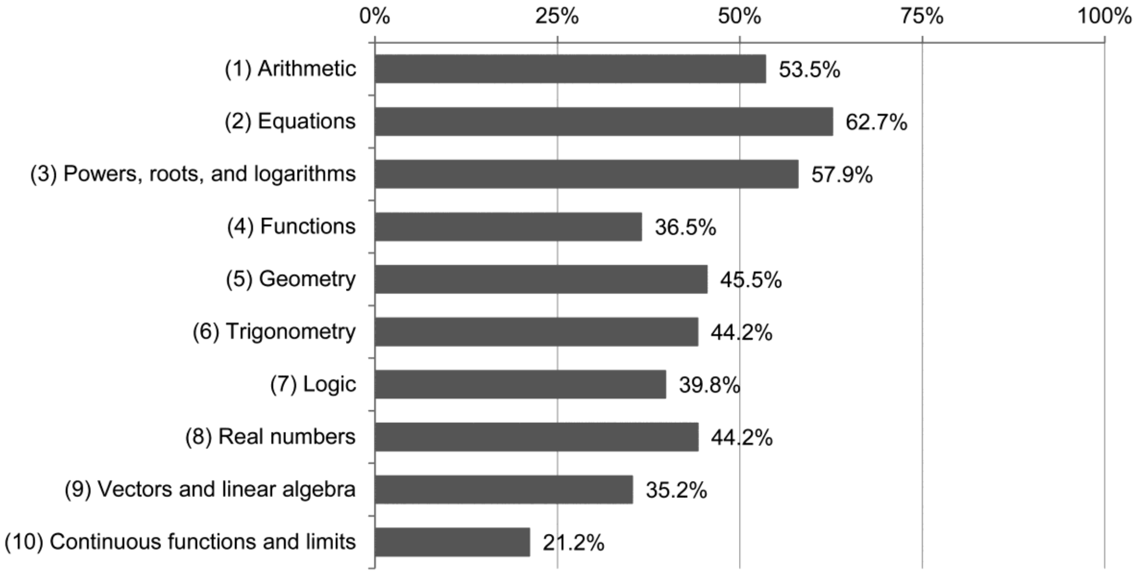



*Figure 11 Diagnostic pre-test results 2012 per mathematical field in per cent (n = 642)*

Looking at the high variation in pre-test results it was not considered useful to thin out the learning material. Instead, it was decided to divide the course curriculum into two parts, “basic” and “extended“. In the revised course design the basic curriculum consisted of the first six modules from *(1) Arithmetic* to *(6) Trigonometry*. The remaining four learning modules *(7) Logic* to *(10) Continuous functions and limit*s were assigned to the non-mandatory “extended” curriculum. These curricular changes also affected the diagnostic feedback which will be discussed in the next section.

#### *5.2.4.3 Diagnostic Feedback*

Based on students’ results in the pre-test the system provided a diagnostic feedback, including the total score and percentages per mathematical field. If these fell below 50 per cent participants were advised to close their knowledge gaps with a related learning module. A considerable number of students had learning recommendations for eight or more mathematical fields (2011: $n$ = 297; 2012: $n$ = 241), which was in contrast to the demand to keep the pre-course manageable for students with broad knowledge gaps (McDowell, 1995) and also appeared to demotivate many participants. Too many recommendations, based on poor results, thus often led to frustration.

> "… if you go in there unprepared, this thing [the entry-test] is a punch in the gut. If you get a result like, you should more or less learn everything from A to Z, from Adam to Eve, that's not very effective, honestly. ... You do the test, submit it to the world wide web, and bang in your face you get the feedback." [group 2013, mechanical engineer]

The evaluation also showed that some students found it difficult to interpret their results and use these results to plan and structure their learning. The diagnostic feedback thus underwent a revision. Based on the new curricular structure, students with below-average pre-test results in more than six categories were advised to focus on the basic curriculum. One exception was the learning module *(7) Logic* which was recommended to all computer science students but not to the remaining four courses.

A second change referred to the issue of "calibration" (Winne, 2004). As students repeatedly reported that they had felt insecure regarding the interpretation of their results, the external reference, "performance of other groups" (Kluger and DeNisi, 1996), was added. In the revised feedback students could compare their own test results (overall and per mathematical category) with that of the previous cohort (see Figure 12).

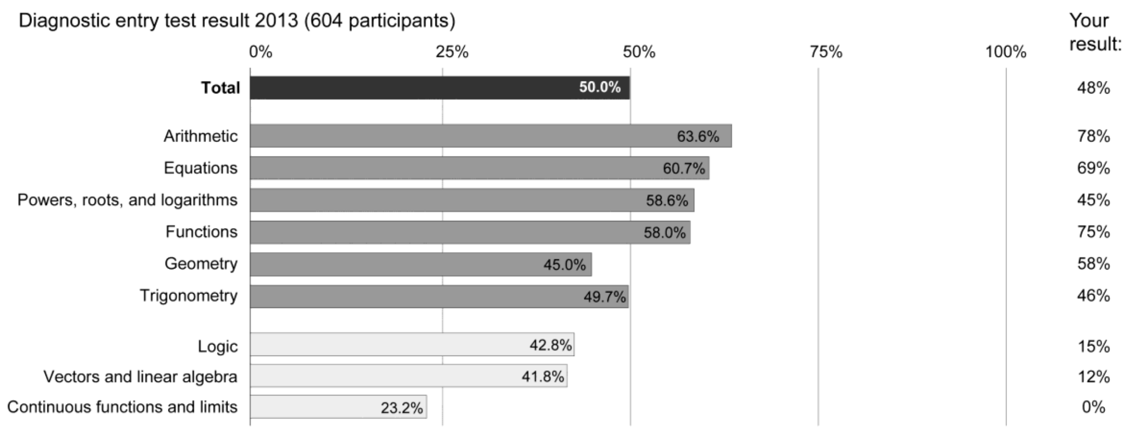



*Figure 12 Screenshot of revised diagnostic feedback: average entry-test results of previous cohort: Overall, six basic categories, four additional categories (translated from German original)*

Furthermore, for the final revision the structure and computation of the diagnostic feedback could be significantly improved by a Moodle plug-in developed by Dreier (2014) for his student research project in computer science. The evaluation of 2014 suggested that the revised diagnostic feedback had resulted in a higher acceptance and was perceived as more helpful. Positive comments on the diagnostic test ("helpful" or "very helpful") rose from 20% in the years 2011 to 2013 to more than 60% in 2014 ("somewhat helpful" = 30%, "not helpful" = 3%).

It also should be stated that not all students considered a poor test result as demotivating or not helpful; some referred to the diagnostic feedback as helpful because it reminded them to prepare for their course and thus raised awareness for the relevance of mathematical skills.

> "Well, ... I would say this 'punch' was quite all right, because many of us feel secure, with nearly-A-grades in mathematics from the *Fachabi* [graduation from a subject-related secondary school], and then you do the test and score really poor, and that makes you wake up and think about study preparation, at least that's what I did". [group 2013, industrial engineer]

#### *5.2.4.4 Learning modules*

In accordance with the above named mathematical fields ten self-contained learning modules were developed, starting in the first year of the project with downloadable PDF-scripts. These scripts were successively transformed into interactive learning modules, combining texts, graphs, animations and videos, examples, and exercises. The concept followed a "traditional" text book structure, with an introduction relating each mathematical field to historical or actual applications. Each subsection was divided into explanations, examples with worked solutions, and exercises. Students were allowed to browse between chapters and independently plan the learning process if they wanted to (McManus, 2000). In 2012 an internal wiki was added, providing additional information on definitions, mathematical expressions or formulae via hyperlinks. At the end of each of the ten modules students could take a subject-related self-assessment, consisting of 10 to 15 randomised items. Feedback to this test comprised a general feedback and detailed solutions for every problem.

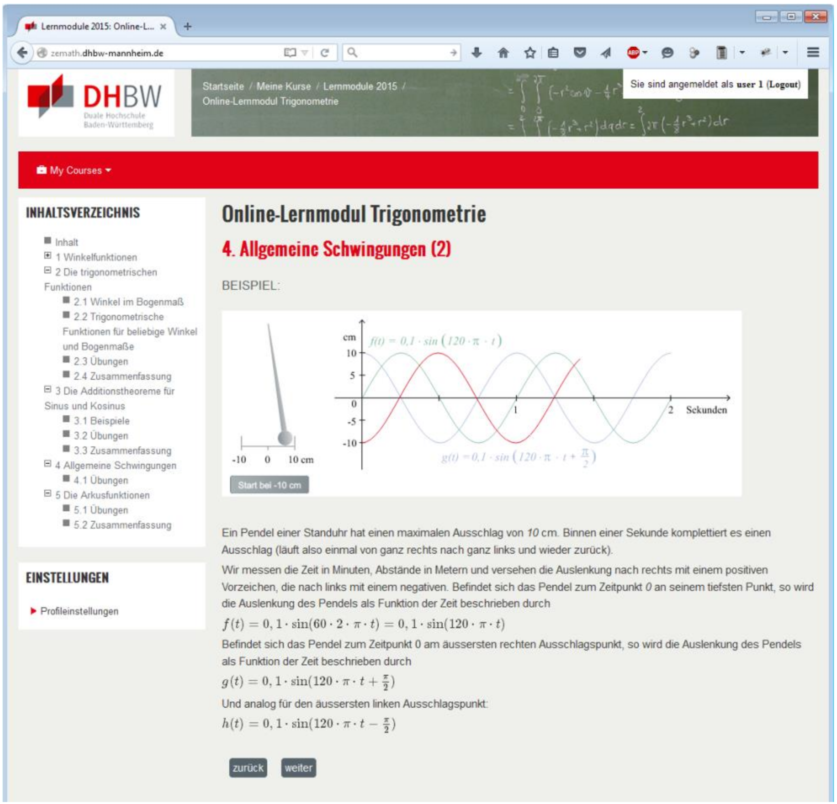



*Figure 13 Screenshot of learning module (6) Trigonometry*

Both contents and structure of the learning material remained under constant revision throughout the study, eliminating many critical points. The evaluations suggested, for example, that the learning modules *(7) Logic*, and *(10) Continuous functions and limits* were perceived as “very difficult”, and poorly structured. By comparison, *(1) Arithmetic*, and (*3) Powers, roots, and logarithms* obtained good to high acceptance.

#### 5.2.4.5 *Additional support*

As “non-traditional” students were expected to have larger deficits and to be less prepared for learning independently a one-week face-to-face course had been provided for this group (2011: $n$ = 44; 2012: $n$ = 84). The evaluations showed that many traditional students, as well, were highly interested in additional support. Some students reported to find it difficult to study alone and to miss face-to-face interaction, others claimed to need additional support in structuring and planning their learning. At the same time it had to be considered that not all students were able to travel and participate in additional face-to-face sessions. It therefore was decided to modularise the programme, with different learning scenarios open for self-selection (Jackson and Johnson, 2013).

In the revised programme the weeklong face-to-face courses were open for all students (regardless of their educational background) but could no longer be provided free of charge. Students could also sign up for an e-tutoring programme that lasted one month. E-tutoring participants had access to the same learning material but the learning process was structured and monitored by e-tutors. Students could discuss problems and test results with peers and e-tutors and had to weekly upload a completed exercise sheet. The diagnostic pre-test was used to assign students with similar patterns to the same e-tutoring group.

#### *5.2.4.6 Post-test*

The post-test marked the end of the study preparation phase and the beginning of the degree programme. It was taken at the university's computer laboratories during induction week. Like the pre-test it addressed the ten mathematical fields and provided a category-based feedback in combination with learning recommendations. Students that still performed poorly in the post-test were advised to attend additional mathematics tutorials during the first semester.

On average, the post-test results were higher than the pre-test results, suggesting a significant increase (2011: pre-test: 49.1, post-test: 61.1; 2012; pre-test: 43.3, post-test: 50.1). By comparison, post-test results of non-participants were quite diverse (2011: 52.8; 2012: 38.9), suggesting some issues with the test design that was still in development (see next chapter 5.2.5)

Students' feedback to the post-test not significantly differed from that to the pre-test, although some students claimed that it had been even more difficult. This also normalised after the design process was completed in 2014.

#### 5.2.4.7 *E-learning assumptions*

The pre-study was also used to confirm three major assumptions related to the use of e-learning (see section 2.5.1.3):

- Cost-saving assumption
- Time and place independency assumption
- Digital natives assumption

As for *cost-saving* and *time and place independency*, the assumptions were applicable for the case of DHBW Mannheim. With more than 70% of the prospective students not stemming from the Mannheim area, or Baden-Wuerttemberg, many students welcomed (and made use of) the opportunity to learn from abroad. Some participants studied at home, others were allowed to do so at the office during internships. Though some students visited the platform at evenings or at night the material was mainly accessed during daytime and on weekdays. In the interviews, many students stated that they had valued the possibility to study at their own pace.

Indications for highly technology-focused and explorative learning styles as postulated by the concept of *digital natives* could not be found. It was quite unexpected, for example, that about 20% of pre-course participants preferred the printed PDF-scripts over the interactive learning modules. 25% preferred the online version and the majority stated that they wanted access to both versions, the interactive module and the downloadable script. In the interviews there also was a quite heterogeneous picture; while some students claimed that they disliked learning with the computer others had enjoyed it.

> "… Anyway, personally, I think it is really difficult to grasp these mathematical issues by looking at a computer screen, so I decided to just download the PDF-files, print them to paper and skip through." [group 2012, industrial engineer]

> "With me it's like, I prefer something real between my hands. It's like with a book and an e-book, I will always prefer the book." [group 2012, mechanical engineer]

> "Yes, in general, I thought it was too bad that there weren't online learning modules for each subject" [group 2012, electrical engineer]

“This interactive stuff was really good, the more of this, the better.” [group 2012, electrical engineer]

A relation between usability acceptance these preferences could not be found. (In general, the LMS’ usability did not give cause for concern; the majority of students called it either “good” or “very good” (2011: 78%; 2012: 70%); 20% (2011), resp. 25% (2012) considered it as “ok”).

While the interactive learning contents were not embraced by all students, there was a general agreement about the usefulness of web-based self-assessment. Participants appreciated that they got immediate feedback and that they could take the tests as often as they liked. Some students used the self-tests at the end of each learning module to pre-structure their learning.

„But there was a final test to every learning module, wasn’t there? … I kind of liked this. I used to start with taking these tests and then have a look at the scores. And if I did not too good, I had another look at the script.“ [group 2012, industrial engineer]

In the evaluation questionnaire as well as in the interviews it was repeatedly suggested by participants to provide even more opportunities to self-assess.

“I think it should be more focused on exercises. My opinion. So I can assess if I can actually do it, because, by only reading I can’t learn it.” [group 2012, industrial engineer]

#### *5.2.4.8 Application of mathematics*

During interviews conducted in the pre-study students repeatedly demanded to be provided with examples for the relevance of mathematics in the engineering practice.

“Well let’s say mathematical arguing, you will only need it if you’re planning to become a mathematician, a lecturer, or whatever it is that mathematicians are doing. But I think for engineers, it is rather the practical relevance and the application that is important. I am really asking myself, later on, when I have to read a structural design, what will I need a mathematical argument for?!” [group 2013, mechanical engineer]

In order to better understand the role of practical applications for the learning process, items related to the provision of “real world” examples were developed for the revised course design. Based on the literature it was hypothesised that students with little or no interest in mathematics could be motivated by this approach (Kendall Brown *et al.*, 2009; Preißler *et al.*, 2010; Young *et al.*, 2011; Härterich *et al.*, 2012; Rylands *et al.*, 2013; Rooch *et al.*, 2014). This issue was to be addressed in the main study research question MQ9. Figure 14 to Figure 16 show examples for this approach.

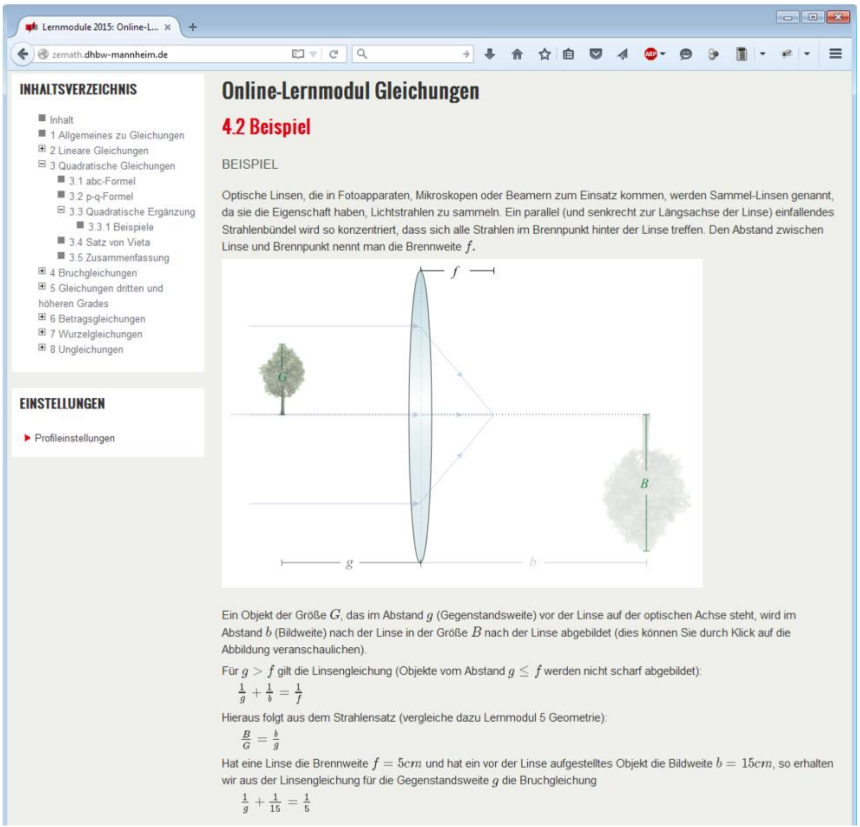



*Figure 14 Screenshot learning module "Equations", practical example optical lenses*

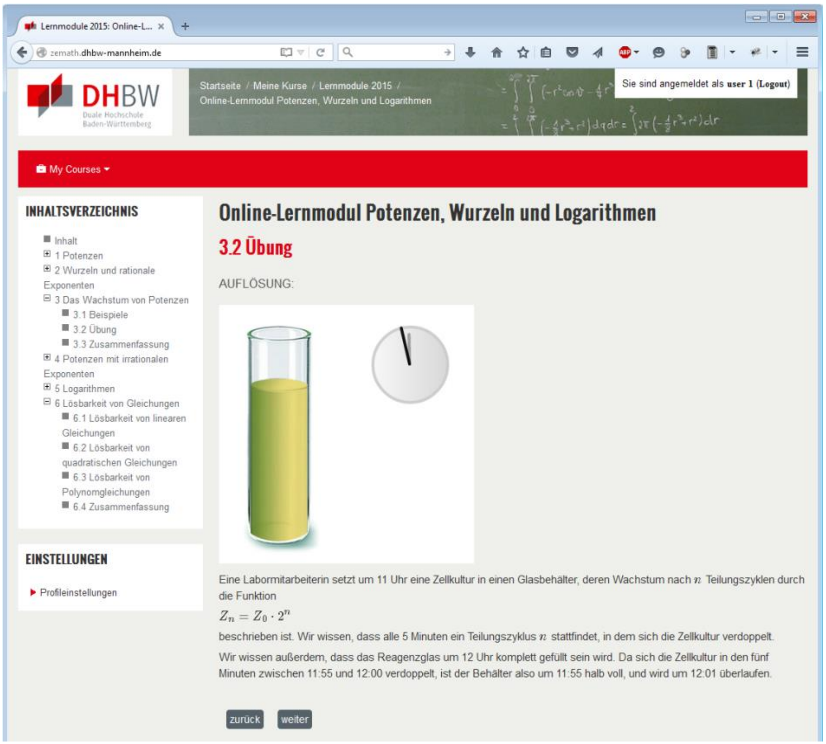



*Figure 15 Screenshot learning module "Squares, roots, and logarithms", practical example exponential function*


*Figure 16 Screenshot self-test learning module "Equations"*

### 5.2.5 Results: Pre-post-test design

Placement tests in mathematics are not mandatory at German universities, therefore the pre-study was used to develop a diagnostic pre-test that (a) informed students about their knowledge level in mathematics, (b) informed them of their learning gains, and (c) could be included in the quantitative analyses. In order to avoid training effects two itemsets of comparable difficulty covering the same topics had to be developed (Kane, 2013). For the evaluation of these tools a probabilistic statistical method was chosen (see also section 2.6.3).

#### *5.2.5.1 Item analysis process*

The first version of the diagnostic pre-test was based on an existing paper & pencil test. Some items could easily be translated to an online version, others had to be rephrased or replaced by more appropriate questions. All items were assigned to one of three difficulty levels (“easy”, “medium”, “difficult”) and three experts (two mathematics lecturers and a mathematics school teacher) reviewed the question pool and suggested changes to content or item difficulty estimation. The goal of this procedure was to develop two tests of “medium” difficulty: Very easy test designs are likely to produce a ceiling effect; students with very high or maximum pre-test results cannot improve any further in the post-test. Conversely, a very difficult test design may disadvantage participants with poor pre-test results, because their chances of performing better in the post-test are rather weak (Marsden and Torgerson, 2012). All item changes were discussed with the expert raters, and then tested with two groups of university students (second semester of computer science) regarding aspects like difficulty, length, and usability. Based on the test results of the 2011 cohort an item analysis was carried out, aiming at the following goals:

*1. Define and align item difficulty.* The tests were designed to address three levels of difficulty (easy, medium, difficult). The item analysis was to show if these assumed difficulty levels could be maintained. Mismatches might indicate a problem with the question stem, or a multiple-choice distractor, therefore the answer patterns of these items were to be analysed, as well.

*2. Eliminate extreme outliers and unfit items.* The item analysis allows identifying items that are extremely easy or difficult and thus fail to deliver information. Rasch model estimations were to reveal if an item was "unfair" for certain groups of participants. For example, a mathematics problem might be embedded in a narrative demanding a high level of verbal proficiency.

*3. Align pre- and post-test difficulty.* Based on the difficulty levels of each item the overall test difficulty was to be estimated with the goal of providing two equally difficult tests. As both tests have a time limit (pre-test: 120 minutes; post-test: 60 minutes) the analysis should also reveal if all items could be answered in the given time. Finally, pre-test and post-test should be equally difficult for different samples.

#### *5.2.5.2 Statistical data model*

For Rasch model estimations the size of the item pool and the sample should not be too small; in the literature, a set of 20 items and 200 participants is considered sufficient (Yen and Fitzpatrick, 2006, p. 133). Hambleton and Swaminathan (2010, p. 308) suggest using sample sizes of $n > 200$ for goodness-of-fit investigations. These demands were met for each of the four cohorts examined in this study, with 506 participants in the first year, 642 in the second, 597 in the third and 603 in the final year. *Note:* Estimations reported in this section were based on test results of participants of both pre- and post-test.

As all test items were dichotomous the single parameter logistic model, or Rasch model, could be applied. Some test items with scores > 1 were transformed to 1 / 0 for the analysis.

For the estimation of item and person parameters the software *Acer ConQuest 2.0* was used. *ConQuest* was developed for the Australian Council for Educational Research (ACER) (Wu *et al.*, 1997). It produces marginal maximum likelihood estimates and can be used for the estimation of both simple logistic models and multidimensional models (Wu *et al.*, 2007). *ConQuest* provides traditional statistics like variance, standard deviation, or Cronbach's α coefficient. For *R*, an open source software environment for statistical computing and graphics (http://www.r-project.org), several packages for IRT estimations are available. For dichotomous items, the *eRm* (extended Rasch modelling) package provides model fit tests, a set of graphical model tests, and the computation of ICCs (Mair and Hatzinger, 2007; Poinstingl *et al.*, 2007).

The following statistical measures were used as a basis for the item analysis:

| | |
|---|---|
| *Mean score* | % correct per item |
| *D* | Discrimination index / item-total correlation (*ConQuest* estimation) |
| *β* | Difficulty parameter (*Conquest* estimation) |
| *MNSQ* | Fit statistics: weighed fit (*Conquest* estimation) |
| *t-test* | Fit statistics *t*-test (*Conquest* estimation) |
| *Wald test* | Additional item "fairness" test (*eRm* estimation) |

*Table 11 Overview of item parameter estimates used for item analysis*

*Mean score:* The mean scores indicate the number of correct answers per item expressed in per cent.

*D discrimination index:* "Traditional" item statistics, estimated by *ConQuest* based on product moment correlation between the scores on this item (number of correct answers) and the corrected total test scores (Wu *et al.*, 2007, p. 167). In the literature on IRT models item discrimination is often referred to as *a*, but in this report the index as used by *ConQuest* will be maintained. A discrimination index *D* above .2 was considered desirable while a discrimination index below .2 would indicate a deviation from the general concept of the test (Cohen, 1988, p. 157).

*β difficulty parameter:* Difficulty index based on Rasch model estimation. Negative values indicate low and positive values indicate high difficulty. The range of this scale is related to the itemset used and thus not based on absolute values. An item's difficulty in relation to the other items of a test, though, should remain the same across different samples. Assuming a test item is fair, it will produce similar difficulty values when answered by a different sample. The values of β typically range from -3 to 3 with values near -2 being very easy and near 2 very difficult (Hambleton and Swaminathan, 2010, p. 36). For the item analysis a difficulty level between -1 and 1 was labelled "medium", β parameters above 1 were labelled “difficult” and β parameters below -1 “easy”. Items with β parameters above +2 and below -2 were considered outliers.

*MNSQ fit statistics:* Infit/outfit indices based on Rasch model estimation. The mean square is calculated by taking the sum of squared residuals averaged over the total number of persons answering the item (Wright and Mok, 2004). It indicates the deviation of observed values from the model estimates, with 1 being a perfect fit (Linacre, 2002). Values above 1.5 indicate underfit, or a low discrimination. Values above 2 indicate an extreme underfit and will distort the measurement system. Values below .5 indicate overfit (very high discrimination, thus so predictable that they do not add very much information to the model). For the analysis a mean square between .8 and 1.2 was considered a good item fit.

*T-test fit statistics:* In addition to the *MNSQ* statistics, the corresponding *t*-test should be observed (Wu *et al.*, 2007, p. 24-25). It indicates problems with item discrimination. If the *t*-statistics have an absolute value that exceeds 2, it is likely that this item’s discrimination is very weak, for example correctly answered by otherwise low performing students.

*W Wald test pass:* The Wald test compares item parameter estimations for different groups of participants, e.g. male / female. If the difference between these groups is significantly different ($p < .05$) the test is not passed, indicating that this item is not equally difficult for different groups of students (Poinstingl *et al.*, 2007, p. 92 f.). For the item analysis the split criterion “mean” was chosen. Thus the test revealed if item estimations differed when answered by the upper or lower half of the sample.

Each of the above listed parameters delivered information on an item’s quality and its contribution to the test. For each decision on changing or replacing an item these measures had to be weighed up against each other, beginning with item difficulty and then deciding why an item did not match their intended difficulty level, or why it did not fit the Rasch model. For better illustration of the process one example is given in the following section. The item analysis as a whole is summarised in the ensuing section.

#### *5.2.5.3 Item analysis example*

The following item was in the 2011 and 2012 diagnostic pre-test in the category "Arithmetic", addressing the subsection "Percentages". It had been rated "easy" by authors and expert raters.

> **Number *a* is 50% smaller than number *b*.**
> **Then *b* is ……………% bigger than *a*.**

The mean score for this item (percentage of correct answers out of 506 students in 2011) was 52.6. With Rasch difficulty estimates of $\beta = -.02$ the item was of "medium" difficulty. The mean square fit statistics for this item (*MNSQ* = 1.1) were in the range of model-fitness (.8 to 1.2) but the corresponding *t*-test outcome was very high (3.7), indicating low discrimination. The classical discrimination index was also poor, with $D = .19$. Still, with the fit statistics not extremely bad and the Wald test passed it was decided to observe this item's discrimination in the revised test version in the following year. The ensuing statistical analysis, though, generated even poorer results for this item. The *MNSQ* now was 1.11 and the corresponding *t*-test = 4.3 with an item-total correlation of $D = .16$. The Wald test was not passed and the item was estimated "medium" difficult, with $\beta = -.14$ (mean = 47.25). As the item had been intended to be "easy" these results indicated a problem with the question stem.

An analysis of students' wrong answers to this item revealed that in both years a third had answered this question with "200" (instead of "100"). It therefore was discussed how to rephrase this item and make it less misleading. It was decided to replace the item by the following version of the problem:

> **Number *b* is 100% bigger than number *a*.**
> **Then *a* is ……………% smaller than *b*.**

It was expected that the item would be easier to understand while still addressing the issue of relativity in percentages.

After the revision the difficulty level $\beta$ was around -1.5, so that the goal of producing an "easy" item had been achieved. The fit statistics and the corresponding *t*-test were satisfying, and the Wald test was passed. This indicated that item parameter estimations for the upper and lower half of the sample did not differ significantly, or put differently, the β parameter estimations were similar for both groups of participants. Thus the revised item met the model requirements.

| | first version | | revised version | |
|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 |
| n answered (n total)* | 504 (506) | 648 (642) | 596 (597) | 596 (603) |
| mean score | 52.6 | 47.3 | 81.5 | 80.8 |
| *D* discrimination index | 0.17 | 0.16 | 0.27 | 0.20 |
| β difficulty estimate | -.02 | -0.14 | -1.54 | -1.53 |
| *MNSQ* weighed fit | 1.10 | 1.11 | 1.01 | 1.07 |
| *t-test* fit statistics | 3.70 | 4.30 | 0.20 | 1.10 |
| *Wald test* passed | yes | no | yes | yes |

*Table 12 Classical and IRT statistics for arithmetic item, with D = item-total correlation, β = Rasch difficulty estimates, MNSQ = fit statistics, t-test fit statistics (all estimated by ConQuest), and Wald test (estimated by eRm) (*not answered = 0 score)*

Figure 17 shows the item characteristic curves for both versions of this item. It can be seen that in the first two years participants with an ability level of zero had a probability of .5 to answer the item correctly (β was close to 0). With the new version of the item, the ICCs in the following two years were shifted to the left; participants with an ability level of zero now had a probability of .8 to answer this item correctly. Figure 17 also shows that the ICCs are not very steep and, accordingly, the traditional discrimination index *D* relatively low, but still in an acceptable range.

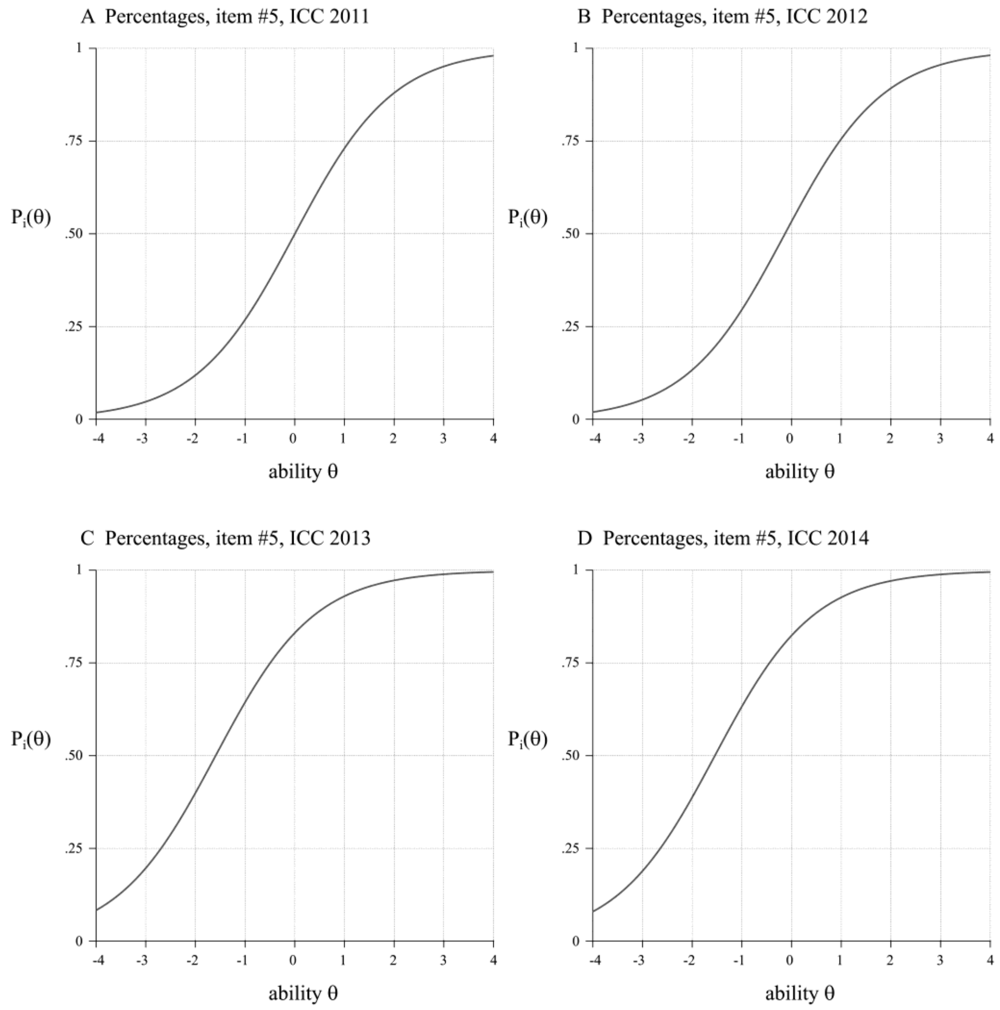



*Figure 17 ICCs, Item characteristic curves, for Percentages item (pre-test), first version in 2011 and 2012 and revised version in 2013 and 2014*

#### *5.2.5.4 Item analysis process*

Based on the procedure described in the previous section each pre- and post-test-item was analysed and, if applicable, changed or replaced. In 2011, the diagnostic pre-test appeared to be more difficult than the post-test. Pre-test mean scores per item ranged from 5.1 to 97.8; expressed as Rasch difficulty estimates this read as $\beta$ = 3.3 for the most difficult and $\beta$ = -4.1 for the easiest pre-test item. The pre-test also contained 12 extreme outliers ($\beta$ above 2. or below -2.). The post-test items showed less extreme results, with means between 15.4 ($\beta$ = 2.6) and 92.3 ($\beta$ = -2.2) and only 3 outliers. Based on the 2011 analysis, 30 out of 89 pre-test items and 12 out of 45 post-test items were subject to revisions.

The 2012 statistical analysis revealed an improved test design with less outliers (8 pre-test and 3 post-test items) and less extreme minimum and maximum difficulty values. The post-test's difficulty had been increased, thus approaching that of the pre-test. At the same time, the pre-test difficulty estimates were even higher than in the previous year. As a consequence the next design phase demanded relaxing the difficulty level of both tests.

For the third analysis "difficult" pre-test items in particular were considered for revision. It also was investigated how many items had remained unanswered. Especially near the end of the pre-test many items had very low answer rates (and thus high difficulty levels), indicating that participants had been running out of time. With a length of 120 minutes it was not found reasonable to add test time, thus it was decided to remove 11 pre-test items and 5 post-test items.

The revised pre-test consisted of 77 items; 11 items had been changed and 11 items had been removed without replacement. In the corresponding post-test 4 items had been changed (and 5 removed), so that it now consisted of 40 items.

*Improved Pre-post-test design*

The abridged pre-post-test design that was used in the following two years delivered more consistent results, with only two pre-test outliers and an appropriate difficulty level.

As a first validity check the issue of non-completion was investigated. Participants had been advised to skip items they were unable answer, therefore not-answered items were found throughout both tests. Near the end, though, the rate increased. For the item analysis it had to be investigated if the difficulty estimations for items placed near the end of the test were significantly higher.

In the much longer pre-test the sections addressing different mathematical fields had been split in two, therefore the answer patterns and difficulty estimations of similar items at different points in time could be compared. For example, the first set of items addressing "Vectors and linear functions" was in the middle section of the test and the second set near the end. This category contained a relatively high number of difficult items and in both itemsets the rate of not-answered items was between 15 and 45%; in the second itemset this rate was between 26 and 53.

| item # | 33 | 34 | 35 | 36 | 67 | 68 | 69 | 70 | 71 |
|---|---|---|---|---|---|---|---|---|---|
| not answered (n) | 270 | 90 | 155 | 101 | 176 | 159 | 211 | 263 | 322 |
| not answered (%) | 44,8 | 14,9 | 25,7 | 16,7 | 29,2 | 26,4 | 35,0 | 43,6 | 53,4 |

*Table 13 Number / percentage of not answered items in "Vectors and linear functions" (first set: item 33-36; second set: item 67-71)*

No item in the category "Vectors and linear functions" was estimated "easy". In the first itemset three items were estimated "medium", one "difficult"; in the second itemset three items were estimated "medium" and two items were estimated "difficult". It may be concluded that the difficulty estimates were affected by an item's position in the test, but that the influence of the mathematical topic was stronger. In both tests, the rather difficult mathematical fields "Vectors and linear algebra" and "Continuous functions and limits" were placed near the end and these items were estimated equally difficult for students who found the time to answer them. Thus the relation between number of items and test time was found manageable, but probably still demanding for students with lower ability. For the 2014 test version (and for the ensuing years 2015 and 2016) no further abridgements were made but the issue of non-completion remained under observation.

Two newly added pre-test items had to be revised in the final year: The first item had been a replacement for an “extremely easy” item addressing linear equations. Another new item in the pre-test category “Logic” was answered correctly by only 12% of the sample and thus was estimated “extremely difficult” ($\beta$ = 2.3). With otherwise good fit the item remained in the test but one distractor was removed. This change, though, did not affect the difficulty estimation, so the item again was an outlier in the final analysis.

Apart from these two items no changes were made to the pre-post-test design in 2014. Figure 18 and Figure 19 show the difficulty estimates for each pre- and post-test item in the final two years. Besides the above described “Logic” item a second outlier was at the other end of the difficulty scale, in the pre-test category “Arithmetic”. The item addressing fractions on a number ray had been added in 2013 and was answered correctly by more than 80% of both cohorts. While it was on the verge of being an outlier in 2013 ($\beta$ = -1.8) it exceeded the predefined limit in the final analysis ($\beta$ = -2.1).

Overall, the number of extreme $\beta$ values was reduced from 15 in the first analysis to 2 in the final year, so that the goal of eliminating outliers was (nearly) achieved. It also could be verified that the tests were equally difficult for both cohorts, as difficulty estimations in 2013 and 2014 were more or less similar.

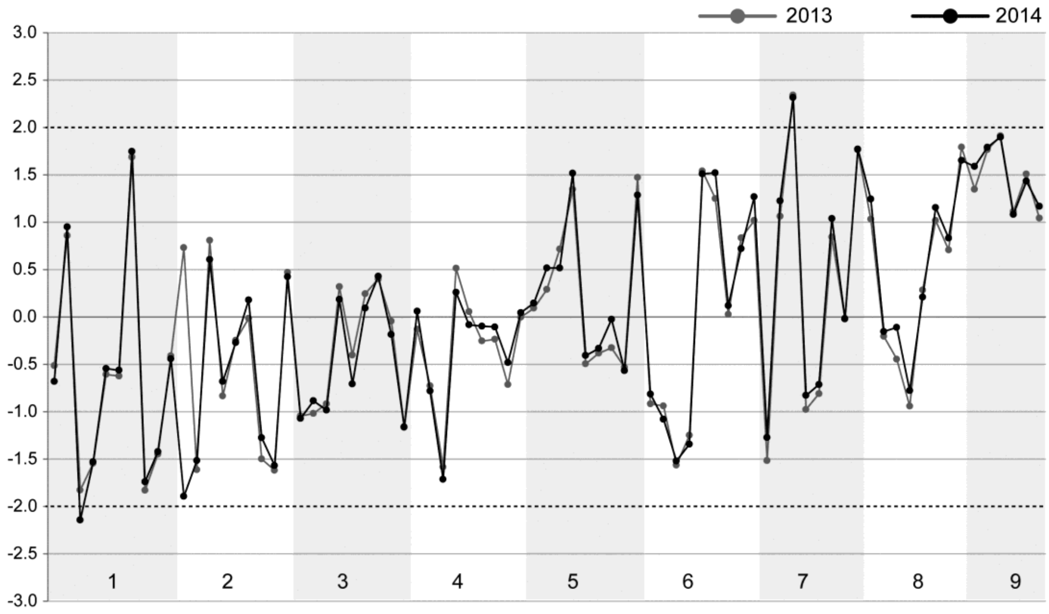



*Figure 18 Pre-test Rasch difficulty estimations (β) in 2013 and 2014, per item, ordered per category: 1 Arithmetic (10 items), 2 Equations (9 items), 3 Powers, roots, logarithms (9 items), 4 Functions (9 items), 5 Geometry (9 items), 6 Trigonometry (9 items), 7 Logic (8 items), 8 Vectors and linear algebra (8 items), 9 Continuous functions and limits (6 items)*

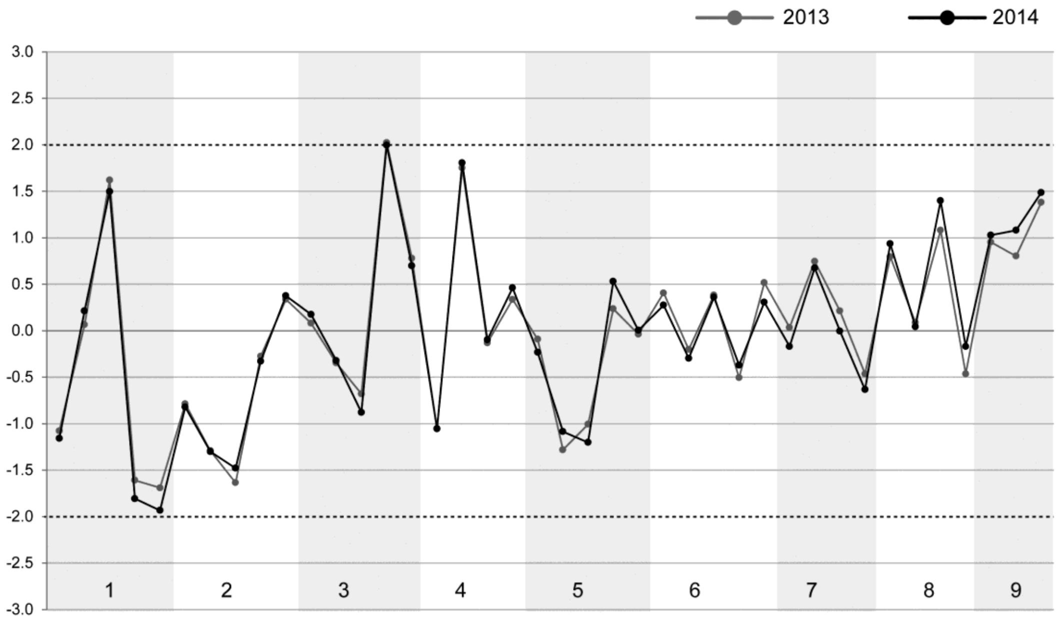



*Figure 19 Post-test Rasch difficulty estimations (β) in 2013 and 2014, per item, ordered per category: 1 Arithmetic (5 items), 2 Equations (5 items), 3 Powers, roots, logarithms (5 items), 4 Functions (4 items), 5 Geometry (5 items), 6 Trigonometry (5 items), 7 Logic (4 items), 8 Vectors and linear algebra (4 items), 9 Continuous functions and limits (3 items)*

The item analysis also was to show if the predefined difficulty levels of each item could be maintained. During the development process a considerable number of items produced deviating results. Some had to be assigned to another difficulty level, others were changed or replaced. 43 of the initially used pre-test items and 23 of the post-test items remained unchanged throughout the study.

| | pre-test | | | | post-test | | | |
|---|---|---|---|---|---|---|---|---|
| | *pre-study* | | *main study* | | *pre-study* | | *main study* | |
| number of… | 2011 | 2012 | 2013 | 2014 | 2011 | 2012 | 2013 | 2014 |
| items total | 89 | 88 | 77 | 77 | 45 | 45 | 40 | 40 |
| very easy items ($\beta < -2$) | 6 | 3 | 0 | 1 | 1 | 1 | 0 | 0 |
| very difficult items ($\beta > 2$) | 6 | 5 | 1 | 1 | 2 | 2 | 1 | 0 |
| overfit items (< 0.8) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| underfit items (> 1.2) | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| fit but critical *t*-test (> 1.95) | 5 | 10 | 7 | 12 | 3 | 6 | 6 | 4 |
| Wald test failed | 29 | 32 | 26 | 27 | 14 | 13 | 11 | 13 |
| Wald test passed | 60 | 56 | 51 | 50 | 31 | 32 | 29 | 27 |
| changed or replaced after revision | 30 | 11 | 2 | 0 | 12 | 4 | 0 | 0 |
| removed without replacement | 0 | 11 | 0 | 0 | 0 | 5 | 0 | 0 |
| unchanged from 2011-2014 | 43 | | | | 23 | | | |

*Table 14 Overview of design revision process 2011-2014*

Cronbach's $\alpha$ as a measure of internal consistency was satisfying throughout the study, with pre-test values between .87 (2011) and .90 (2014) and post-test values between .86 (2011) and .85 (2014).

With each change to the tests as a whole, the difficulty level per mathematical field was affected. The difficulty estimates in the first six basic mathematical fields cover the complete range between $\beta = -2.0$ and 2.0, as intended. Only the mathematical field "Equations" contained a relatively large number of easy items, with a maximum difficulty of only $\beta = .8$.

The mathematical fields "Logic", "Vectors and linear algebra", and "Continuous functions and limits" had a considerably higher difficulty level. For these categories it was not possible to develop items estimated "easy" by the model. The same applies to the subsection "Logarithms" of "Roots, squares, and logarithms". This result supported evaluation and group interview outcomes as students had repeatedly claimed that some test contents had been completely new to them. This was the case for the above named topics, and for "Trigonometry", as well.

#### *5.2.5.5 Pre-post-test similarity*

After estimating each item's difficulty level and eliminating outliers, the third goal of the item analysis was the alignment of pre- and post-test difficulty. In the literature on test development it is usually suggested to randomly assign itemsets to pre- or post-test participants (e.g. Rijmen, 2010). Due to technical and administrative restrictions a randomised AB-CD design was not manageable for this study. Thus a quasi-experimental group design was chosen, using students who had not participated in the pre-test, nor the pre-course, as a "control group" (denoted as group B). Presuming two equally difficult tests, this group's post-test results were expected to be similar to the larger group's pre-test results.

| | | |
|---|---|---|
| Pre-test | A | |
| Post-test | A | B |

A Pre-test and post-test participants: Students who took both tests, answered the statistics questionnaire, and started the degree programme.

B Post-test only participants: Students that did not participate in the pre-test (nor the pre-course) but took the post-test and started the degree programme (ca. 20% of each cohort).

| | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|
| A Pre- and post-test participants | 506 | 642 | 597 | 603 |
| B Post-test only participants | 209 | 186 | 119 | 105 |

*Table 15 Database for item analysis 2011-2014*

Two scales were available to compare pre- and post-test results. First, students' sum scores (number of correct answers in %) and second, each participant's ability as estimated by the Rasch model. In IRT, the ability trait indicates the probability of a participant to answer any test item correctly. Unlike raw scores, the ability trait estimated in IRT is not observable, but a "label that is used to describe what it is that a set of items measures” (Hambleton and Swaminathan, 2010, p. 55). By including the information derived from the difficulty estimate β, the ability trait accounts for the difficulty level of each item in a test. The ability trait, or person parameter θ is measured on the same (logit) scale as the item parameter, with positive values indicating a higher, negative values a lower ability level. *ConQuest* generates a Weighted Likelihood Estimate WLE. It expresses the deviation between the expected and observed weighted raw score of a participant (Yen and Fitzpatrick, 2006, p.136).

Figure 20 shows the test results of the final test design in 2013 and 2014, expressed in sum scores and WLE (ability trait θ). In conjunction with the difficulty scale the units of the ability scale typically range from -4 to 4. Note that in the post-test-only group in 2013 one extreme outlier with an ability of 4.9 (sum score = 100%) was estimated.

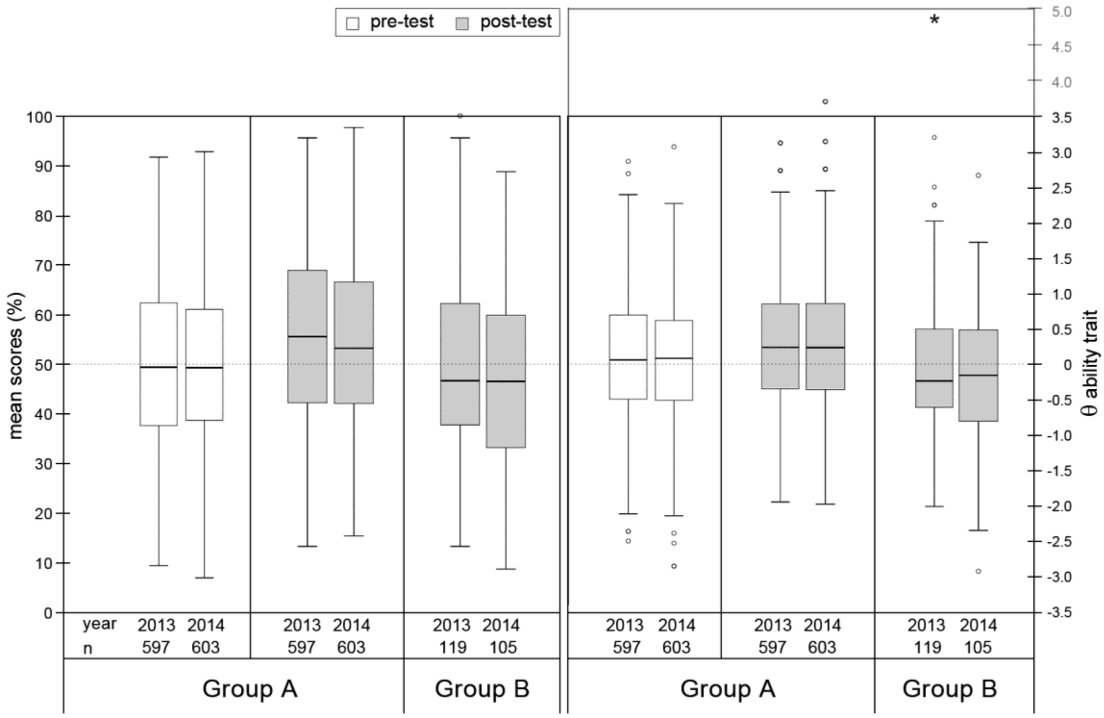



*Figure 20 Pre-test-post-test mean scores / ability scores 2013 and 2014, participants both tests (group A) and participants post-test only (group B)*

| | Group A | | | | | | | | Group B | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pre-test | | | | post-test | | | | post-test | | | |
| | 2013 | | 2014 | | 2013 | | 2014 | | 2013 | | 2014 | |
| | % | θ | % | θ | % | θ | % | θ | % | θ | % | θ |
| n | 597 | 597 | 603 | 603 | 597 | 597 | 603 | 603 | 119 | 119 | 105 | 105 |
| mean | 50.0 | .1 | 49.7 | .1 | 55.1 | .3 | 55.2 | .3 | 49.3 | .0 | 47.3 | -.2 |
| median | 49.4 | .1 | 49.4 | .1 | 55.6 | .2 | 53.3 | .2 | 46.7 | -.2 | 46.7 | -.2 |
| variance | 276 | 1 | 255 | 1 | 321 | 1 | 305 | 1 | 339 | 1 | 330 | 1 |
| stand. dev. | 16.6 | .9 | 16.0 | .9 | 17.9 | 1.0 | 17.5 | 1.0 | 18.4 | 1.1 | 18.2 | 1.0 |
| stand. err. | .7 | .0 | .7 | .0 | .7 | .0 | .7 | .0 | 1.7 | .1 | 1.8 | .1 |
| min. | 9.4 | -2.5 | 7.1 | -2.8 | 13.3 | -1.9 | 15.6 | -2.0 | 13.3 | -2.0 | 8.9 | -2.9 |
| max. | 91.8 | 2.9 | 92.9 | 3.1 | 95.6 | 3.1 | 97.8 | 3.7 | 100 | 4.9 | 88.9 | 2.7 |

*Table 16 Pre-test-post-test mean scores / ability scores 2013 and 2014, participants both tests (group A) and participants post-test only (group B)*

The first assumption had been that post-test scores and ability levels of group B (post-test only) would be lower than those of group A (pre- *and* post-test). This was the case, in both years group A's post-test means were around 55 ($\theta = .3$), whereas the scores in group B were 49.3 ($\theta = 0$) in the first, and 47.3 ($\theta = -.2$) in the second year.

Group B's post-test results also were expected to equal group A's pre-test results. With pre-test means around 50 ($\theta = .1$ in both years) group A outperformed group B in both years, suggesting that post-test difficulty was higher than that of the pre-test.

Another possible explanation for this effect was that group A's ability level was higher. As students had not been randomly assigned to either group it could not be ruled out that the two groups' preconditions differed. In order to investigate this issue, Chi-square tests were performed on variables potentially related to prior knowledge in mathematics. It was found that in most years the composition of group A and B differed. For example, around 75% of group A students had graduated from a German *Gymnasium* with *Abitur* while in group B this rate was around 70% (on average over the four cohorts). Only in the second year of the pre-study, though, this difference was statistically significant ($n = 837$; $df = 2$; $\chi^2 = 8.47$; $p = .014$). It also was found that 30% of group A students had "very good" grades in mathematics, vs. only 20% in group B. The difference between mathematics grades was significant in the first two years of the pre-study (2011: $n$ = 678; df = 2; $\chi^2$ = 16.176; $p$ < .001) (2012: $n$ = 815; df = 2; $\chi^2$ = 12.634; p = .002). Age, or year of graduation, appeared not to differ in the two groups.

Although differences between both groups were not significant in two out of three years, group B appeared to be weaker than group A. Thus it appeared reasonable to choose a conservative design with a (potentially) more difficult post-test.

#### 5.2.5.6 *Rasch model conformity*

Table 17 and Table 18, Figure 21 and Figure 22 show the pre-test and post-test results that were collected for the item analysis. After the pre-test had been too difficult in 2011 and 2012 and the post-test too easy in 2011 and too difficult in 2012 the final versions delivered consistent results in 2013 and 2014. Pre-test mean scores were around 50 and the ability level θ around .1, while post-test mean scores were around 55 and θ in both years 0.3.

| | 2011 | | 2012 | | 2013 | | 2014 | |
|---|---|---|---|---|---|---|---|---|
| | % | θ | % | θ | % | θ | % | θ |
| n | 506 | 506 | 642 | 642 | 597 | 597 | 603 | 603 |
| mean | 49.12 | .12 | 43.32 | -.25 | 5.01 | .09 | 49.72 | .08 |
| median | 48.48 | .06 | 41.84 | -.31 | 49.41 | .05 | 49.41 | .09 |
| variance | 152.06 | .51 | 173.16 | .54 | 276.24 | .79 | 255.41 | .75 |
| stand. dev. | 12.33 | .71 | 13.16 | .74 | 16.62 | .89 | 15.98 | .86 |
| stand. err. | .55 | .03 | .51 | .03 | .68 | .04 | .65 | .04 |
| min. | 8.08 | -2.98 | 1.20 | -2.52 | 9.41 | -2.50 | 7.06 | -2.84 |
| max. | 82.83 | 2.19 | 91.84 | 2.82 | 91.76 | 2.85 | 92.94 | 3.07 |

*Table 17 Pre-test mean scores / ability scores θ 2011-2014 (participants both tests)*

| | 2011 | | 2012 | | 2013 | | 2014 | |
|---|---|---|---|---|---|---|---|---|
| | % | θ | % | θ | % | θ | % | θ |
| n | 506 | 506 | 642 | 642 | 597 | 597 | 603 | 603 |
| mean | 61.14 | .61 | 50.05 | -.04 | 55.06 | .28 | 55.16 | .28 |
| median | 61.00 | .49 | 50.00 | -.08 | 55.56 | .23 | 53.33 | .23 |
| variance | 271.99 | .93 | 263.98 | .78 | 32.91 | .92 | 304.89 | .92 |
| stand. dev. | 16.49 | .96 | 16.25 | .88 | 17.91 | .96 | 17.46 | .96 |
| stand. err. | .73 | .04 | .64 | .03 | .73 | .04 | .71 | .04 |
| min. | 1.00 | -2.45 | 8.00 | -2.66 | 13.33 | -1.95 | 15.56 | -1.97 |
| max. | 96.00 | 3.46 | 94.00 | 3.04 | 95.56 | 3.11 | 97.78 | 3.71 |

*Table 18 Post-test mean scores / ability scores θ 2011-2014 (participants both tests)*

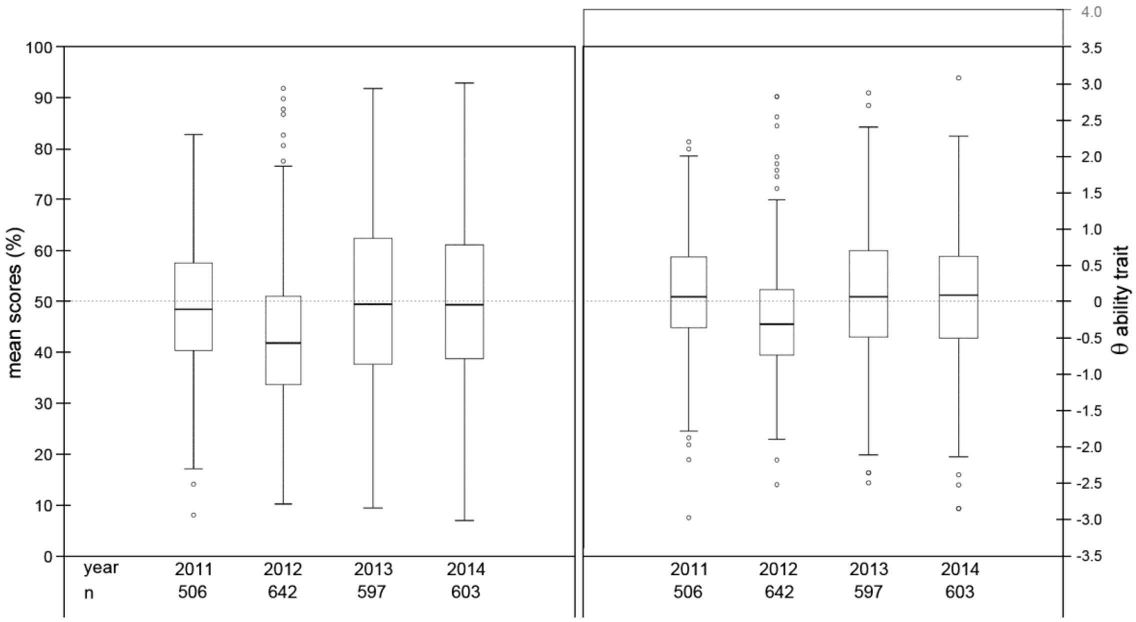



*Figure 21 Boxplots pre-test mean scores / ability scores θ 2011-2014 (participants both tests)*

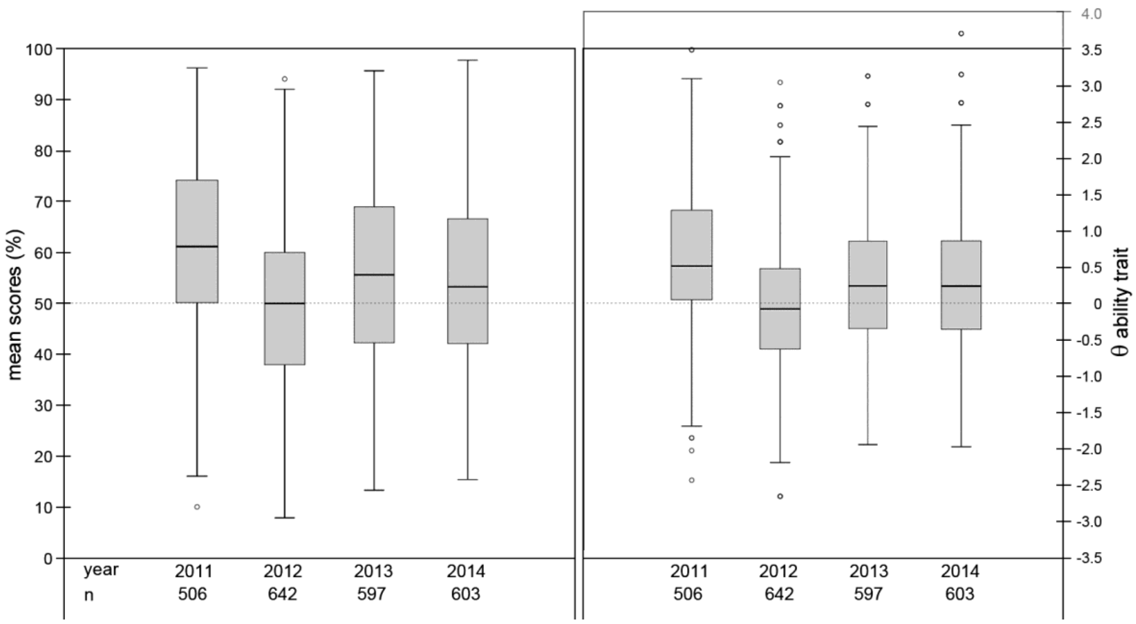



*Figure 22 Boxplot post-test mean scores / ability scores θ 2011-2014 (participants both tests)*

At the same time, not all Rasch model requirements could be met. Rasch conformity will only be given when all test items address the same latent ability trait which was not the case in this study. At this point different approaches could be used in order to achieve model-fitness. For example, coherent topics could be clustered to subsets of items (“testlets”, or “item bundles”; see Yen and Fitzpatrick, 2006, p. 120).

Clustering of different groups of students then might reveal that different sets of model parameters are valid for different subpopulations (Rost, 1997, p. 449). Alternatively, a less restrictive IRT model could be chosen (e.g. two-parametric Birnbaum model, see Strobl, 2012, p. 50f.).

It was, however, decided against such an approach. As Yen and Fitzpatrick suggested, IRT analyses should serve as “informative but not definitive” sources of information (Yen and Fitzpatrick, 2006, p. 141). For the context of this study it was hypothesised that the ability measured, “prior knowledge in mathematics”, is a multifaceted construct addressing more than just one latent trait. Items that demand the knowledge of a certain method, or formula, are unfair to students who do not have this knowledge or forgot how to use it. Considering the diverse educational backgrounds some items inevitably were unfair to certain groups of students.

Another reason might be that Rasch model demands conflicted with the overall didactical goal of delivering a comprehensive self-diagnosis. The pre-test had been designed to arouse awareness for the relevance of basic skills. In that context, unfair items had the role to hint at knowledge gaps and thus were an integral part of the concept. As the post-test led to more balanced results, with less misfit items, it may be hypothesised that many students eventually managed to “revive” their school knowledge between the two tests. Concluding, in order to better understand the relations between different groups of participants and groups of test items more detailed statistical analyses would be needed, but were considered disproportionate for the interest of this study.

### 5.2.6 Summary and discussion

Concluding, PQ1 “Does the course design provide an adequate e-learning environment?”, PQ2 “Does the pre-post-test design used for this study adequately represent / measure prior knowledge in mathematics and learning gains in the pre-course?”, and PQ3 “Do the scales representing students attitudes and their use of learning strategies show internal consistency?” could be answered positively.

The assumption that a web-based pre-course would be welcomed by prospective engineering students was confirmed; the majority of students did not stem from the Mannheim area or was on internships and would otherwise not have been able to participate in the course. Three revisions had resulted in an e-learning environment that was positively evaluated and showed no concern for negative or unexpected influences caused by usability issues, technical or practical problems. A modular course design, open for all students throughout the summer, with additional support in face-to-face taught or e-tutored courses, was found an adequate approach for the highly heterogeneous group of prospective first year engineering students. The main study was to reveal how the two types of additional support would affect “at risk” students’ learning gains.

A particular focus was set on formative self-assessment. The revision of the diagnostic feedback had resulted in higher levels of acceptance for this tool and thus, hopefully, a better learning experience. The main study was to reveal how “at risk” students made use of this tool and if it resulted, for example, in higher levels of self-reflection.

The demand for more opportunities to self-assess was met by increasing the number of test items in the learning management’s question bank. Many of these items were designed under the premise of giving examples for the application of mathematics, either in everyday word problems or in technical and engineering contexts. It was to be evaluated in the main study if and how such an approach supported “at risk” students’ interest in or attitude towards the pre-course in mathematics.

Finally, the outcomes of the pre-post-test design revision process suggested that the final version was a considerable improvement and now delivered reliable indication of first year students' basic knowledge in mathematics and of their learning gains in the pre-course. The described approach of combining classical and probabilistic statistical methods proved to be quite laborious but also highly viable for identifying "bad" items in a very complex and voluminous test design. While the strict demands of the Rasch model could not be met for the complete set (see discussion in section 5.2.5.6), the goal of designing a "medium difficult" pre-post-test design was achieved; extreme values in both directions were eliminated and the risk of floor or ceiling effects minimised. Internal reliability was confirmed by comparing difficulty estimations based on two cohorts. The correlation of this measure with academic achievement and its external reliability were to be confirmed in the main study.

## 5.3 Main study

The main study combined a comprehensive quantitative investigation with a qualitative analysis addressing the student experience. First, hypotheses based on the literature and the pre-study were tested quantitatively by confirmatory statistical analysis (Tashakkori and Teddlie, 2009). The qualitative part of the main study aimed at connecting the quantitative observations with “at risk” students’ experiences in the pre-course and during their first months at university. For this purpose, the sub-research questions were re-addressed in a series of semi-structured interviews with first year students. The content of the interview protocol referred to results obtained from previous investigations; it was expected that these would be enriched and sharpened by the interviews (Johnson and Onwuegbuzie, 2004). At the same time, they were to show if further topics that had not yet been found relevant would emerge.

The outcomes are reported chronologically, with the quantitative strand in section 5.3.5, and the qualitative strand in section 5.3.6.

### 5.3.1 Study design

*Quantitative strand*

The quantitative strand of the main study aimed at identifying variables that could be related to an improvement of “at risk” students’ first year mathematics performance. Anonymised administrative data representing educational backgrounds or prior secondary performance were available for all students and could be connected to their pre-course user IDs. Furthermore, two web-based questionnaires were administered to pre-course participants. The first covered questions about students’ educational background, their mathematics grades, and their attitudes towards mathematics.

Attitudes towards mathematics was modelled using subscales from the Trends in International Mathematics and Science Study TIMSS (Kadijevich, 2006; Mullis *et al.*, 2012). The TIMSS items appeared appropriate as the majority of pre-course participants had finished school a few weeks or months earlier and their attitudes towards the subject were based on their secondary school learning experiences.

The second questionnaire was answered after pre-course participation. It covered general questions about satisfaction with the programme and it also addressed students' use of learning strategies in the pre-course. For this investigation subscales from the LIST inventory were used (Schiefele and Wild, 1994), a German version of the "Motivated Strategies for Learning Questionnaire MSLQ" (Pintrich *et al.*, 1991).

From the LMS Moodle log files were collected describing students' access to learning modules, the number of test attempts and forum posts, furthermore results in the diagnostic pre-test and post-test. The difference between pre-and post-test, the gain score, was considered a measure of pre-course learning outcomes. Table 19 gives an overview of the collected variables. The quantitative data were inputted into *SPSS V 23* and *R V 3.4.3*. Descriptive analyses, ANOVA, linear and multiple regressions were used to analyse and control for interactions between predictive variables. A *p*-value of less than .05 was considered statistically significant; *p*-values of less than .01 or .001 were reported if applicable.

| Variable | Source |
|---|---|
| Educational and demographic background<br>1 Gender<br>2 Age<br>3 Gap between secondary and tertiary education<br>4 Federal state<br>5 Type of secondary school<br>6 Mathematics grades at school<br>7 Secondary GPA | survey / administrative data base |
| Prior knowledge in mathematics | pre-test score in % |
| Attitude towards mathematics | 12 Likert-scaled items |
| Use of learning strategies | 7 Likert-scaled items |
| Time on task | 1 Likert-scaled item, 2 closed items |
| Task strategies | log files |
| Pre-course learning gains | pre-post-test difference |
| Pre-course participation | y / n |
| First year study success | exam grades Mathematics I |
| Final year study success | GPA, retention / withdrawal |

*Table 19 Overview of quantitative variables main study*

*Qualitative strand*

The qualitative strand of the main study explored the topics that had not been clarified or answered comprehensively in the quantitative strand. It was expected that in-depth interviews with course participants would explain and enrich previous outcomes. At the same time, the interviews were to show if further themes that had not yet been addressed would emerge.

As this study aimed at understanding the learning behaviour and needs of the "at risk" group, interview participants were purposefully chosen from this group (Patton, 2002). The single interviews, ranging from 25 to 35 min, took place seven months after induction week (the date of post-test participation) and one month after students had taken the exam Mathematics I. They were conducted using a semi-structured interview technique that allowed responding to the situation at hand. A list of open-ended questions was used to guide the interviews but varied in order, wording or focus (Robson, 2011) (see Appendix G.1 for an overview of items). Participants were also asked to complete a short questionnaire addressing demographic information and educational background. All interviews were digitally recorded, transcribed verbatim by the author, checked for accuracy, and loaded into *MAXQDA V12*. Each transcript was coded by examining the raw data and identifying statements referring to the study interest, using a qualitative content analysis (Mayring, 2000; Mayring, 2014). The analysis was performed at two levels, within each case and across cases (Stake, 1994; Yin, 2003). The main categories were based on the research questions and were used to repeat the quantitative evaluation and to re-test the main hypotheses (Flyvbjerg, 2006). Issues that had not yet been covered but recurred across interviews were also categorised and, if considered relevant for the study interest, included in the final report (Pascale, 2011). Despite the small sample size, the analysis reached saturation with several themes recurring across interviews.

### 5.3.2 Data collection

Table 20 gives an overview of the different issues that were explored throughout the study and the different quantitative and qualitative approaches used.

| | Data collection method | |
|---|---|---|
| *Issue explored* | *quantitative* | *qualitative* |
| Educational and demographic background | survey | semi-structured interview |
| Prior knowledge in mathematics | quiz (diagnostic pre-test) | semi-structured interview |
| Attitude towards mathematics | survey | semi-structured interview |
| Pre-course participation | y / n | |
| Type of course and support level | Self-study / face-to-face / e-tutored course | |
| Use of learning strategies | survey | semi-structured interview |
| Learning activities, time on task | survey, log files | semi-structured interview |
| Pre-course learning gains | quiz (post-test) | |
| First year study success | exam grades Mathematics I | |
| Final year study success | GPA, withdrawal | |
| Relevance of basic mathematics knowledge for engineering course | Multiple linear regression | semi-structured interview |
| Relevance of pre-course participation for engineering course | ANOVA, multiple linear regression | semi-structured interview |

*Table 20 Study interests and data collection methods*

### 5.3.3 Sample

The *quantitative strand* of the main study was carried out with the cohort of 2014 who participated in the revised version of the pre-course programme ($n$ = 603, non-participants 2014: $n$ = 105). This report uses this data set as an example; major analyses were repeated with the cohorts of 2015 and 2016 and supported these results (see also Appendix F.2).

Some student data of previous cohorts were included, as well. The cohort of 2011 graduated in 2014, thus their administrative data could be used to estimate relations between first and final year study success (see sub-research question MQ1 and section 5.3.5.1.) To establish internal validity, these estimations were repeated for the cohorts of 2012 and 2013.

The *qualitative strand* was carried out with nine first year "at risk" students from the cohort of 2016. They had participated in the pre-course and had obtained a below-average pre-test result. Four interviewees had participated in the additional e-tutoring course, one student had participated in a face-to-face course, as well. Most interview participants were between 19 and 20 years old, two students were above 25.

The students had attended secondary school at different German federal states, or outside the EU. Seven interviewees had finished secondary school in the same year, two had already studied / worked in another field. Five students had attended a traditional German *Gymnasium*, one came from a technical *Gymnasium* and one had attended a vocational school and a *Gymnasium*. Their secondary GPAs were between 1.4 (very good) and 3.0 (note that in Germany grades above 4.0 are failed).

Seven students were enrolled in the course Computer Science. This course had relatively poor pass rates in Mathematics I, with 43 per cent of students failing their first mathematics attempt in 2014. Otherwise, computer science students were not significantly different from other engineering students regarding their preconditions or prior knowledge level. However, two interviews with mechanical engineering students were carried out at the end of the study to investigate differences between course programmes.

| Cohort | 2014* | 2015 | 2016 |
|---|---|---|---|
| First year students | 722 | 718 | 774 |
| Pre-course participants (pre-test + post-test) | 603 | 551 | 596 |
| Questionnaire I: demographic + attitude scales | 593 | 535 | 582 |
| Questionnaire II: evaluation + learning strat. scales | 205 | 117 | 122 |
| First year students | 708 | 707 | 767 |
| Post-test only participants | 105 | 156 | 171 |
| Semi-structured single interview participants | | | 9 |
| First year performance (Mathematics I) | 674 | 660 | 747 |

Final year / study success:

| Cohort | 2011** | 2012** | 2013** |
|---|---|---|---|
| Cumulated grade point average, retention | 589 | 650 | 554 |

*main study data set

**cohort of 2011 evaluated in 2014; cohort of 2012 in 2015; cohort of 2013 in 2016

*Table 21 Sample overview main study*

### 5.3.4 Ethical considerations

For the preparation of the main study the German data privacy laws on federal and state level as well as ethical considerations were accounted for. Suggestions for the anonymisation of quantitative and qualitative data were followed, e.g. usage of replacements and pseudonyms or removal of direct and indirect identifiers (UK Data Service, 2013; Gebel *et al.*, 2015).

The university's data privacy official gave ethical approval. Pre-course participants were informed on the purpose of the study and agreed that their learner data were collected, anonymised, and evaluated. Students aged under 18 provided a parental consent. Tests and questionnaires were completed voluntarily and anonymously.

Interview participants were informed of the research interests and that their statements would be recorded. They agreed that some statements would be published in an anomymised way that would prohibit disclosure of their identity (Walford, 2005; Kelly, 2009). Granting anonymity was considered particularly important for the single interviews that were carried out in the final phase of the study (see section 5.3.6). These interviews were prepared by giving short information about background and goal of the study in selected first year mathematics lectures. An e-mail invitation with an attached information sheet was then sent to all potential participants. Students willing to participate were asked to respond to the researcher by email. Students attended the face-to-face interviews voluntarily and were informed that all data were treated confidentially.

In a preparatory conversation interviewees were informed of the research interest and method and that their data and statements would be anonymised and treated confidentially (Punch, 1994, p. 90). It was to be avoided that participants could be identified by "deductive disclosure" (Kaiser, 2009, 1632). Thus statements that would make a student clearly identifiable were omitted in this report. In Appendix G.2 a summary of each interview session is provided.

### 5.3.5 Quantitative results

#### *5.3.5.1 First year mathematics performance as a predictor of study success in engineering (MQ1)*

In this section the approach to identifying the first year examination Mathematics I as an early indicator of study success in engineering is reported. “Study success” was defined by two variables, final year GPA and the dichotomous variable retention / withdrawal (Robbins *et al.*, 2004; Plant *et al.*, 2005). As the university’s administrative data base did not inform if, and if yes, why a student had withdrawn from the degree programme the two dependent variables were estimated based on ECTS (European Credit Transfer System) scores and missing data. This approach is exemplified with the cohort of 2011. For this cohort, 126 withdrawals and 589 completed degrees were identified. The ECTS scores suggested that the majority of withdrawals occurred during the first year. In order to differentiate between voluntary and required student withdrawal only datasets which fell into more than one of the following categories were defined as required withdrawals:

- one or more than one examination failed
- a cumulated grade point average (GPA) of 3.0 or higher, indicating a high number of poor results (note that at German universities an exam is passed between 1.0 (= very good result) and 4.0 (= very poor result))
- missing values in more than one examination

This analysis produced 76 withdrawals related to poor performance and 31 voluntary withdrawals.

| | *n* | % |
|---|---|---|
| Graduated with Bachelor degree | 589 | 82.4 |
| Withdrawal | 126 | 17.6 |
| - Withdrawal poor grades | 76 | 10.6 |
| - Withdrawal good grades | 31 | 4.3 |
| - Missing* | 19 | 2.7 |

*Table 22 Study success and withdrawals of the 2011 cohort, participants of at least one test (pre- or post-test) (n = 715) (*missing values in GPA = did not take any examination = withdrawal)*

The first variable describing “study success” was coded into “1 graduation” and “0 required withdrawal”. Students who had voluntarily withdrawn were excluded from the analysis of student performance. As a second variable students' final GPA was available, representing student performance on a scale from 1 (very good) to 4 (note that in the German tertiary system grades between 4.01 and 5.0 are a failure).

Examination results in the five degree programmes (computer science, electrical engineering, mechanical engineering, mechatronics, and industrial engineering) were then related to the two measures of study success. Examinations with high correlations in more than one course were considered potentially predictive of study success. Table 23 lists significant correlations between GPA and grades in eight subjects taught in some or all of the degree programmes, in a second year seminar paper and in the final project.

| | total | | Computer science | | Electrical engineering | | Mechanical engineering | | Mecha-tronics | | Industrial engineering | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *r* | *n* | *r* | *n* | *r* | *n* | *r* | *n* | *r* | *n* | *r* | *n* |
| Mathematics I | .62 | 660 | .62 | 106 | .67 | 121 | .65 | 214 | .73 | 139 | .58 | 80 |
| Mathematics II | .66 | 617 | .60 | 101 | .69 | 113 | .65 | 196 | .74 | 130 | .69 | 77 |
| Electrical Eng. I | .63 | 334 | | | .68 | 121 | | | .60 | 139 | .68 | 74 |
| Physics | .57 | 425 | .62 | 38 | .49 | 113 | .51 | 149 | .54 | 51 | .72 | 74 |
| Thermodynamics | .45 | 202 | | | | | .44 | 193 | | | .85 | 9 |
| Feedback Control Sys. | .56 | 300 | | | .49 | 102 | .56 | 166 | | | .71 | 32 |
| Eng. mechanics I | .62 | 294 | | | | | .64 | 214 | | | .59 | 80 |
| Construction I | .34 | 213 | | | | | .34 | 213 | | | | |
| Seminar paper | .44 | 586 | .52 | 96 | .36 | 103 | .34 | 191 | .44 | 122 | .62 | 74 |
| Final project | .59 | 572 | .65 | 98 | .52 | 95 | .53 | 189 | .62 | 121 | .68 | 69 |

*Table 23 Significant correlations between examination results and final year GPA (grade point average), 2011 cohort per degree programme (p < .01 for all correlations)*

Nearly all examinations significantly correlated with GPA, but Mathematics I was the first year exam with the strongest correlation ($r$ = .62; $n$ = 660; $p$ < .01). By comparison, the 2011 first year mechanical engineering exam Construction I had a correlation coefficient of $r$ = .34 ($n$ = 213; $p$ < .01). The best correlation of all examinations, $r$ = .74, was found for Computer science II, a third year exam ($n$ = 102; $p$ < .01). Mathematics II and Physics also showed good correlations with GPA and are taught in all courses. In order to estimate the predictive power of these exam scores linear regressions were performed on the dependent variable GPA (e.g. Tabachnick and Fidell, 2014). As the German grading system is counter-intuitive and may interfere with other scales, e.g. test scores or Likert-scales, all examination scores were reversed, so that 5 now represented the upper and 1 the lower end of the scale.

A single linear regression model using Mathematics I as a predictor of GPA was significant and explained 38% of the variance in GPA, with $R^2 = .38$; $F = 405.77$; $df = 1, 658$; $p < .001$ (see Table 24). In this equation, a rise of one point in Mathematics I predicted a .39 rise in GPA. Similar relations could be replicated for the cohorts of 2012 and 2013.

| | 2011 | | | 2012 | | | 2013 | | |
|---|---|---|---|---|---|---|---|---|---|
| | *B* | *SE B* | β | *B* | *SE B* | β | *B* | *SE B* | β |
| (constant) | 1.11 | .06 | | 0.94 | .06 | | 0.91 | .06 | |
| Mathematics I | 0.39 | .02 | 0.62* | 0.48 | .02 | 0.62* | 0.47 | .02 | 0.70* |
| $R^2$ (adjusted) | | 0.38 | | | 0.38 | | | 0.48 | |
| $F$ for change in $R^2$ | | 405.77 | | | 478.49 | | | 622.26 | |
| Durbin-Watson stat. | | 1.789 | | | 1.740 | | | 1.765 | |

*Table 24 Single linear regression on dependent variable GPA (grade point average) with independent variable Mathematics I (reverse coded)(2011: n = 660; 2012: n = 779; 2013: n = 665); *p < .001*

For Mathematics II and Physics, single linear regressions produced similar predictions. When all three variables were included in the model, more than 50% of the variance in GPA could be explained, and the influence of all three variables remained significant ($p < .001$). In this combined model, Mathematics I had the weakest effect of all three exams, indicating that students' grades at the end of the degree programme were more representative for overall success than those from the first year. As the Physics exam is not taken by all engineering courses, another regression was performed with Mathematics I and Mathematics II, only. With these two variables, up to 55% of variance in GPA could be accounted for.

Finally, the potential of Mathematics I in predicting student withdrawal was tested. A binary logistic regression was performed on the dichotomous variable "withdrawal". It was expected that an increase in grades in Mathematics I would affect participants' log odds of succeeding in the degree programme (Peng *et al.*, 2002).

| | 2011 | | 2012 | | 2013 | |
|---|---|---|---|---|---|---|
| | *B* | *Odds Ratio* | *B* | *Odds ratio* | *B* | *Odds ratio* |
| (constant) | -4.99 | .01 | -2.70 | .07 | -3.61 | .03 |
| Mathematics I | 2.66* | 14.30 | 1.50* | 4.49 | 1.99* | 7.28 |
| Nagelkerke pseudo $R^2$ | 0.46 | | 0.29 | | 0.46 | |
| $\chi^2$ (likelihood ratio) | 171.04; $p < .001$ | | 147.48 ; $p < .001$ | | 209.47; $p < .001$ | |

*Table 25 Binary logistic regression on dependent variable GPA (grade point average) with independent variable Mathematics I (reverse coded) (2011: n = 660; 2012: n = 776; 2013: n = 665); *p <.001*

Table 25 shows the outcomes of this analysis. In 2011, for every increase in grades in Mathematics I, the odds of completing the degree programme were 14.3 times greater than the odds of withdrawing (withdrawal = 0; completion = 1). This relation was significant for all three years (odds ratio 2012: 4.5; 2013: 7.3; $p < .001$), but the impact was weaker in 2012 ($R^2 = .29$). Note that there had been a school reform in some German federal states; secondary education was reduced from nine to eight years, resulting in an even more heterogeneous group of first year students in that year. With a variance of 46% accounted for in 2011 and 2013, the model failed to clearly predict student withdrawal based on Mathematics I alone, but the exam was identified a significant indicator of the risk to fail.

Concluding, the results demonstrated a significant influence of Mathematics I results on both cumulated GPA and student withdrawal. Compared to other examinations taken in the first two semesters, Mathematics I had the strongest predictive power and its relation to study success was nearly as strong as that of Mathematics II, or Physics, which are taken at a much later point in time. Thus the hypothesis was supported that the first year exam Mathematics I was a useful early indicator of subsequent study success and it appeared reasonable to use Mathematics I results as an dependent variable for all subsequent analyses.

### 5.3.5.2 *Pre-test results as a predictor of first year performance in mathematics (MQ2)*

Regression analyses were carried out to verify the assumption that results in the diagnostic pre-test were predictive of the exam Mathematics I. Demographic and school-related variables are also potential predictors of tertiary achievement, thus were included in the multiple regression. Table 26, Model A shows the outcomes of a regression analysis with the seven factors gender, age (in years), gap between school and university (in years), German federal state (five biggest states), type of secondary school (vocational, technical *Gymnasium*, traditional *Gymnasium*), mathematics grades at secondary school (1-4), and secondary GPA (1-4). Four variables showed significant relations to Mathematics I grades: the dummy variable federal state (Bavaria) tested against the baseline (Baden-Wuerttemberg), and type of secondary school, mathematics grades and secondary GPA. The regression was significant ($p < .01$) and accounted for 21% of the variance in Mathematics I.

When added to the model, the diagnostic pre-test significantly contributed to explaining Mathematics I and $R^2$ was increased to 33% (Table 26, Model B). According to this model, a step up in pre-test results (in per cent) was related to an increase in Mathematics I grades of .025. Thus students with a pre-test mean score of 40 were predicted Mathematics I grades .5 above those of similar students with a pre-test mean score of 20.

Compared to the other variables, diagnostic pre-test results were the strongest predictor of first year mathematics performance. Secondary school GPA was the second best predictor in this model. Each increase in secondary school GPA (plus 1) was related to an increase in Mathematics I of plus .44.

| | Model A | | | Model B | | |
|---|---|---|---|---|---|---|
| | *B* | *SE B* | β | *B* | *SE B* | β |
| 1 Gender | -.06 | .13 | -.02 | .14 | .12 | .05 |
| 2 Age | .03 | .05 | .05 | .03 | .05 | .06 |
| 3 Gap school / university | -.01 | .07 | -.01 | -.04 | .06 | -.04 |
| 4 Fed. state: R-P | .14 | .12 | .06 | .08 | .11 | .04 |
| 4 Fed. state: Hesse | .06 | .12 | .03 | -.02 | .11 | -.01 |
| 4 Fed. state: NRW | -.06 | .15 | -.02 | -.05 | .14 | -.02 |
| 4 Fed. state: Bavaria | .54 | .16 | .16** | .47 | .15 | .14** |
| 5 Type of school: S-GYM | .19 | .18 | .07 | -.10 | .17 | -.04 |
| 5 Type of school: G-GYM | .53 | .17 | .24** | .19 | .16 | .09 |
| 6 Math. grades: good | .32 | .12 | .16** | .16 | .11 | .08 |
| 6 Math. grades: very good | .30 | .15 | .13 | .00 | .15 | .00 |
| 7 Secondary school GPA | .64 | .11 | .33** | .44 | .10 | .23** |
| Diagnostic pre-test score (%) | | | | .03 | .00 | .40** |
| $R^2$ / $R^2$ adj. | .21 (.19) | | | .33 (.31) | | |
| $F$ for change in $R^2$ | 1.03** | | | 16.67** | | |
| Durbin-Watson statistics | 2.02 | | | 2.009 | | |

*B*: unstandardised regression coefficient; *SE B*: standard error; β: standardised regression coefficient; significance levels: *p < .05; **p < .01

[a]Federal state Baden-Wuerttemberg = baseline; [b]Vocational school = baseline versus S-GYM (subject-related Gymnasium) and G-GYM (Gymnasium); [c]Math. grades poor = baseline

*Table 26 Regression analysis for variables predicting Mathematics I (n = 465). Model A: Students' preconditions when entering university; Model B: Diagnostic pre-test score added*

Note that eleven outlying cases were removed from the 2014 dataset, due to an extreme Mahalanobis distance (Tabachnick and Fidell, 2014, p. 203). Evaluation of regression assumptions (normality, linearity, and homoscedasticity of residuals, autocorrelation and collinearity) indicated no further cause for concern.

In the following paragraphs the outcomes of this analysis are discussed in relation to the literature on predictors of tertiary achievement.

*Interactions between predictive variables*

Interactions between variables were identified for gender, age, and educational background. Female students, for example, often showed better first year performance than male students and in some models this effect was significant. These results were in alignment with observations made in the descriptive analyses that women more often had traditional educational backgrounds and good or very good secondary school grades compared to male students (see section 5.1). In the literature, investigations of the relation between gender and performance in mathematics or science have led to mixed results. Some studies suggest that female students more often perform poorly or express negative attitudes towards mathematics (Frey *et al.*, 2008; Amelink, 2012; Pustelnik, 2014) whereas others have reported them to outperform male students (Johnson and Kuennen, 2006; Richardson *et al.*, 2012). For engineering students, Zhang *et al.* reported significant but not consistent effects of gender on study success, at some universities positively and at others negatively influencing graduation, thus most probably moderated by other variables (Zhang *et al.*, 2004). Other some studies found no effect on study success (Xie and Shauman, 2005; Faulkner *et al.*, 2014). As female students are underrepresented in engineering courses it is generally difficult to separate the influence of gender on academic achievement in engineering (Ackerman *et al.*, 2013). Regarding the interest of this study it could be concluded that female students, based on their educational background, were less likely to be in the “at risk” group. Otherwise gender appeared not to significantly differentiate between students.

Inconsistent observations were made regarding students’ *age*, respective the length of the *gap between secondary and tertiary education*. Younger students, on average, showed higher first year performance, and the risk to withdraw appeared to increase with age. Again, these results were moderated by cognitive variables, as traditional students usually are younger than students with a non-traditional background. There also were some heteroscedasticity issues as the majority of students were between 18 and 21 years old whereas in the much smaller group of older students the dataset was very heterogeneous (note that age ranged from 22 to 49). It could be drawn from the data that older students tended to withdraw more quickly if facing performance issues, but beyond this very weak trend age appeared to be unrelated to study success.

Some effects were caused by the *federal state* in which secondary school was attended, suggesting that some of the changes to secondary education in Germany negatively influenced student performance (as suggested by Knospe, 2011, as well as Greefrath *et al.*, 2016). However, with a high interaction with other school-related preconditions these effects were relatively weak and might as well be found irrelevant in the further course of the project.

The *type of secondary* school was found highly influential in the first model (A), with significantly poorer performance for students from vocational schools and for students with non-traditional backgrounds. These outcomes supported studies from Germany (Polaczek and Henn, 2008; Knospe, 2011; Greefrath *et al.*, 2014) and Europe (Faulkner *et al.*, 2014; van Soom and Donche, 2014). However, in this study type of school was no longer significant after the diagnostic pre-test was added (model B), suggesting a large variation in students' basic knowledge within the three school types.

*Mathematics grades at school* were also predictive of Mathematics I, but in the multiple model this variable showed less powerful results than expected from the literature (Zhang *et al.*, 2004; Ehrenberg, 2010; Faulkner *et al.*, 2010). As pre-test results are a very similar measure of domain-related prior knowledge they probably overpowered the impact of grades.

Comparing the two best predictor variables found in this study, pre-test results outperformed *secondary GPA*. After the removal of pre-test results from the multiple model, $R^2$ decreased from .33 to .22. When secondary GPA was removed from the model, $R^2$ decreased to .30. Pre-test mean scores alone accounted for more than 20% of the variance in Mathematics I, whereas in a single model with final school grades $R^2$ was only .14.

The outcomes of this study confirm previous research that either secondary GPA or pre-test / placement test results are good predictors of achievement in engineering. With 33%, the overall variance explained with this model was not extremely high but comparable to other studies.

Ackerman *et al.* reported a $R^2$ of .37 in cumulated GPA for a regression model combining sets of cognitive and metacognitive variables. In their study, placement test scores and high school GPA together accounted for 23% of the variance in first year GPA (Ackerman *et al.*, 2013, p. 919). In a meta study by Robbins *et al.* (2004), the variance in GPA accounted for by traditional measures like placement test scores and high school GPA were around 22%, whereas Richardson *et al.* reported an $R^2$ of .28 for the multiple model employed in their meta study on academic performance (Richardson *et al.*, 2012, p. 371). In the latter study, high school GPA was the best traditional predictor of study success, whereas other authors found that pre-tests or placement tests in mathematics and science were a better measure (e.g. Kuncel and Hezlett, 2007; for STEM also Ackerman *et al.*, 2013).

Concluding, the hypothesis that pre-test results are a significant predictor of first year mathematics performance at DHBW Mannheim was supported by this study. Based on these estimations students were considered “at risk” when their mean score in the diagnostic pre-test was below 50. All subsequent analyses were carried out with a focus on this group of students.

#### 5.3.5.3 *Impact of pre-course participation on first year performance (MQ3)*

After having established the relevance of prior knowledge in mathematics for study success in engineering it was investigated if participation in the pre-course would show a moderating effect on this relation.

A comparison between pre-course participants (students who participated in the pre-test and the post-test; $n$ = 603) and non-participants (students who participated in the post-test only; $n$ = 105) suggested a significant difference in first year mathematics performance. On average, pre-course participants obtained significantly higher grades in Mathematics I, the distance accounting for .5 grades (ANOVA: $F(1, 672) = 28.3$, $p < .001$). The difference in pass rates was significant, as well ($n$ = 674; $df$ = 1; $\chi^2 = 37.712$; $p < .001$). see Table 27) (see also Appendix F.2)

| | Mathematics I pass rate | Mathematics I grades[a] |
|---|---|---|
| Pre-course participation | 95.0 | 2.8 |
| No pre-course participation | 77.1 | 3.3 |
| total | 92.4 | 2.8 |

[a]average grades, measured on a linear scale from 1 (=A) to 5, an exam graded > 4.0 was failed

*Table 27Mathematics I pass rate and grades of 2014 pre-course participants (n= 578) versus non-participants (n=96) (missing / first year withdrawals: n = 34)*

As students had self-enrolled into the pre-course these results were not to be overemphasised. Descriptive analyses did not reveal significant differences, but in the group of non-participants the variance appeared to be even larger, from a considerable number of high performing students (who probably had not felt the need to participate in the pre-course), to a relatively large group of students with a high risk to fail. On average, their diagnostic test results were poorer, albeit not significantly (note that for these students the post-test was the first test; see also Figure 23). Furthermore, it could be assumed that students who took the diagnostic pre-test and participated in the pre-course showed an overall higher engagement, resulting in a bias that affected this group’s first year performance throughout the study. The main interest was to show if the pre-course had improved first year performance of "at risk" participants.

In 2014, 603 students had participated in both tests, achieved an average pre-test score of 49.7 and an average post-test score of 55.2. By comparison, students who had not participated in the pre-test achieved a post-test mean score of 47.3. The boxplots in Figure 23 illustrate the deviations from these mean scores; in both groups there was a large variance in test results.

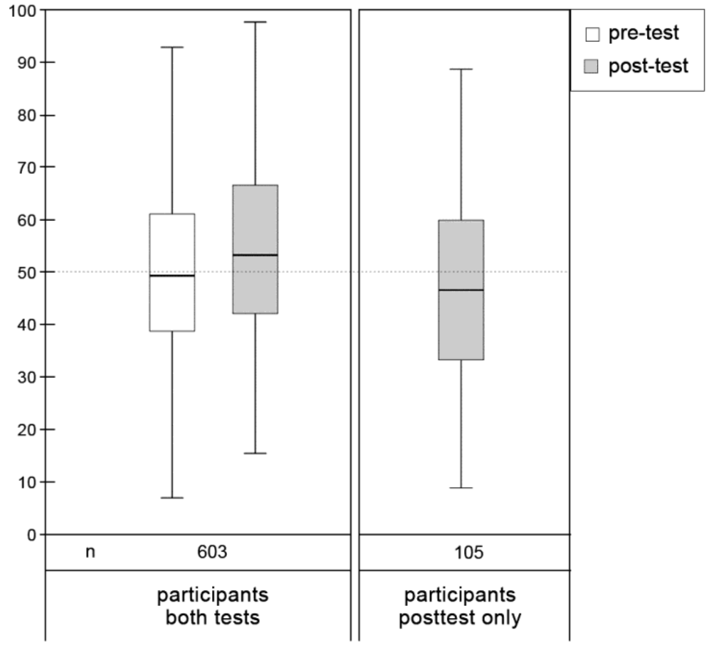



*Figure 23 Pre- and post-test results 2014: participants both tests (n = 603) in comparison to participants post-test only (n = 105)*

The average gain score (post-test minus pre-test) for the 2014 cohort was 5.4 (median = 5.1), with a maximum value of 61.8 and a minimum of -37.5. Students with poor pre-test results (mean score < 50), who were considered the "at risk" group, had an average gain score of 8.3 (median = 7.3; max. = 61.8; min. = -23.4). Students with poor prior knowledge thus showed higher improvement between pre- and post-test. It had been hypothesised that a higher gain score would positively affect first year performance in mathematics. This variable was therefore added to the regression model (as described in section 5.3.5.2, Table 26). The gain score indeed significantly contributed to explaining Mathematics I achievement

(*B* coefficient gain score = .014; see Table 28, Model C). Compared to the dominant role of prior knowledge, this effect was not very strong, thus a noticeable change in Mathematics I was only predicted for students with very high learning gains. For example, a student with a gain score of 20 was predicted an increase in Mathematics I grades by .28, compared to a similar student with a gain score of Zero.

| | Model B | | | Model C | | |
|---|---|---|---|---|---|---|
| | *B* | *SE B* | β | *B* | *SE B* | β |
| 1 Gender | .14 | .12 | .05 | .17 | .12 | .06 |
| 2 Age | .03 | .05 | .06 | .05 | .04 | .09 |
| 3 Gap school / university | -.04 | .06 | -.04 | -.07 | .06 | -.08 |
| 4 Fed. state[a]: R-P | .08 | .11 | .04 | .05 | .11 | .02 |
| 4 Fed. state[a]: Hesse | -.02 | .11 | -.01 | -.05 | .11 | -.02 |
| 4 Fed. state[a]: NRW | -.05 | .14 | -.02 | -.07 | .14 | -.02 |
| 4 Fed. state[a]: Bavaria | .47 | .15 | .14** | .37 | .15 | .11* |
| 5 Type of school[b]: S-GYM | -.10 | .17 | -.04 | -.10 | .16 | -.04 |
| 5 Type of school[b]: G-GYM | .19 | .16 | .09 | .13 | .16 | .06 |
| 6 Math. grades[c]: good | .16 | .11 | .08 | .17 | .11 | .08 |
| 6 Math. grades[c]: very good | .00 | .15 | .00 | -.06 | .14 | -.02 |
| 7 Secondary school GPA | .44 | .10 | .23** | .38 | .10 | .20** |
| Diagnostic pre-test score (%) | .03 | .00 | .40** | .03 | .00 | .49** |
| Gain score (%) | | | | .01 | .00 | .18** |
| $R^2$ / $R^2$ adj. | .33 (.31) | | | .35 (.33) | | |
| $F$ for change in $R^2$ | 16.67** | | | 17.47** | | |
| Durbin-Watson statistics | 2.009 | | | 2.001 | | |

*B*: unstandardised regression coefficient; *SE B*: standard error; β: standardised regression coefficient; significance levels: *p < .05; **p < .01

[a]Federal state Baden-Wuerttemberg = baseline; [b]Vocational school = baseline versus S-GYM (subject-related Gymnasium) and G-GYM (Gymnasium); [c]Math. grades poor = baseline

*Table 28 Hierarchical regression analysis for variables predicting Mathematics I (n = 465). Model B: students' preconditions when entering university versus Model C gain score added*

With an average gain score of plus 8.3 the "at risk" group showed significantly higher learning gains than students with a good or very good pre-test performance (gain score = 2.3) (ANOVA: $df1 = 1$; $df2 = 601$; $F = 31.994$; $p < .001$). It had been hypothesised that the "at risk" group would also show a higher increase in Mathematics I performance and thus benefit more from pre-course participation. However, when the regression was carried out for each group separately the effect of gain score decreased for “at risk” students (*B* coefficient gain score = .011) in comparison to the rest of the sample (*B* coefficient gain score = .016). The hypothesis that “at risk” students overproportionally benefitted from pre-course participation thus was not supported.

The following main study sub-research questions, *MQ4* to *MQ7*, zoomed in on the different elements of the learning process and their influence on pre-course learning outcomes, with a focus on the group of “at risk” students.

#### 5.3.5.4 *Impact of attitude on "at risk" group's learning gains (MQ 4)*

Two subscales from the Trends in International Mathematics and Science Study TIMSS were used. Five items from the subscale LM "Liking mathematics" addressed students' positive or negative feelings towards mathematics or mathematics learning. The subscale SCLM "Self-confidence in learning mathematics" represented students' ease, or difficulty, to learn mathematics (Kadijevich, 2006; Mullis *et al.*, 2012). After removal of two outliers, the scales (12 items) showed an acceptable internal consistency, with Cronbach's α = .87. Previous research reported α-values between .80 and .95 for scales addressing students' self-confidence (Parsons *et al.*, 2009; Zimmerman *et al.*, 2011).

Note that, based on observations made in the pre-study, the third subscale "Value mathematics" had been removed from the questionnaire. Statements like "It is important to do well in mathematics" or "I need to do well in mathematics to succeed in my course of study" were agreed or strongly agreed upon by up to 90% of the sample and only a minority disagreed or disagreed strongly. Not surprisingly, this scale was unrelated to pre-test results or any other measure.

| How much do you agree with these statements about mathematics? (on a scale from 1 to 5) | | scale |
|---|---|---|
| 1 | I am interested in mathematics | LM |
| 2 | I enjoy learning mathematics | LM |
| 3 | I look forward to the mathematics lectures at university | LM |
| 4 | At school, mathematics was my favourite subject | LM |
| 5 | I enjoy problems that are related to technical applications | LM |
| 6 | I enjoy problems that are related to (chosen degree programme) | LM |
| 7 | Mathematical proofs are interesting | LM |
| 1 | I learn things quickly in mathematics | SCLM |
| 2 | Mathematics is harder for me than any other subject* | SCLM |
| 3 | I am good with formulae | SCLM |
| 4 | I am confident that my knowledge will be sufficient for university | SCLM |
| 5 | I feel well prepared for my course of study | SCLM |

*Table 29 Attitude towards mathematics subscales "LM Liking Mathematics" and "SCLM Self-confidence in Mathematics"(Kadijevich, 2006; Mullis et al., 2012)*

All attitude items correlated with diagnostic pre-test results, suggesting that a positive attitude towards mathematics was related to a higher level of prior knowledge. A critical point were the often skewed distributions: participants much more often expressed positive attitudes towards mathematics, or felt reluctant to express negative attitudes, leading to small case numbers. For example, only 13% ($n$ = 77) of first year students were on the negative side of the statement “I enjoy learning mathematics” (strongly disagree: $n$ = 15; disagree: $n$ = 62), whereas 63% agreed ($n$ = 277) or strongly agreed ($n$ = 89). The literature suggested that particularly at the beginning of the course first year engineering students might express over-positive attitudes towards mathematics (Besterfield-Sacre *et al.*, 1996; Meyer and Eley, 1999); however, the skewness of the scales might also indicate that students’ answers had been influenced by social desirability.

Looking at students’ prior knowledge level, there was a significant positive correlation between pre-test results and nearly all attitude items, so that the hypothesis was supported that attitude towards mathematics was positively correlated with prior domain knowledge and thus a covariate (Robbins *et al.*, 2004; Richardson *et al.*, 2012).

An impact of the attitude scales on gain score could not be observed; particularly in the group of “at risk” students both measures were completely unrelated to each other. Thus the hypothesis was rejected that a positive attitude would affect the outcome of the pre-course learning process (Pintrich, 1999).

#### *5.3.5.5 Impact of time management and organisational strategies on “at risk” group’s learning gains (MQ 5)*

For this investigation two subscales addressing organisational strategies, time management and effort regulation from the LIST instrument were used. LIST is a German version of the “Motivated Strategies for Learning Questionnaire MSLQ” (Pintrich *et al.*, 1991) adapted for tertiary education (“*Lernstrategien im Studium*”, Schiefele and Wild, 1994). In contrast to previous research, items related to effort regulation were unrelated to the rest of the scales. For example, the statement “I often felt so bored that I quit and did not finish the learning module." was more or less ignored by participants, 38% did not answer this item. To a statement addressing persistence "Even when an exercise was dull and uninteresting, I did finish it and solved the problem" students neither agreed or disagreed. As effort regulation items did not pass the test on homogeneity of variance or were unrelated to the rest of the scale they were removed from this analysis.

Even then, Cronbach's α was not in an acceptable range (α = .70; *n* = 175, items = 7) and not all items correlated above .4 (Bühner, 2006). A factor analysis suggested that four items (see Table 30, 1 to 4) loaded on a common factor that might be described with "managing the learning process" (α = .74).

These four items were significantly related to each other, and to pre-test results, indicating that students able to manage their learning process had a higher level of prior knowledge in mathematics, as well (Weinstein *et al.*, 1988b; Entwistle and McCune, 2004; Carson, 2011; Credé and Phillips, 2011; Richardson *et al.*, 2012; Broadbent and Poon, 2015). These relations, however, were never linear, so that these variables only allowed to differentiate between very good students who "strongly agreed" to an item like "I usually managed to keep to my schedule" (*n* = 43; pre-test mean score = 58.6) and the rest of the sample.

| How much do you agree with these statements about your learning in the pre-course?<br>(on a scale from 1 to 5) | |
|---|---|
| 1 | I usually managed to keep to my schedule |
| 2 | The learning material was so voluminous, I did not know where to begin* |
| 3 | I just did not have enough time for learning* |
| 4 | I always followed a certain learning schedule |
| 5 | I studied in the evenings and on weekends, as well |
| 6 | I studied in a place where I could concentrate on learning |
| 7 | I invested a lot of time into the study preparation |

*Table 30 Time management and organisational strategies MSLQ subscales (Pintrich et al., 1991)*

Eley and Meyer (2004) reported similar effects from their attempt to model learner behaviour in mathematics. Although a cluster analysis had shown a good consistency the scales showed non-linear relations to student achievement in an undergraduate course, with "'superior' students ... the only ones exhibiting an 'ideal' pattern." (Eley and Meyer, 2004, p. 447). The authors suggested that the development from an ineffective to a proficient learner could not be described by simple steps, but should rather be seen as a complex and irregular process. For e-learning environments, Martin (2012), as well, found that mainly high performing students would make use of organisational strategies.

Concluding, the hypothesis that the use of time management and organisational strategies would be positively correlated with pre-course learning gains was not supported by this study. In particular, the learning strategies items showed no influence on learning gains of the "at risk" group.

Detailed item analyses suggested significant relations between an efficient use of learning strategies and a high level of prior knowledge, so that the hypothesis that the use of time management and organisational strategies was positively correlated with prior domain knowledge and thus a covariate was partially supported.

#### *5.3.5.6 Impact of time on task on "at risk" group's learning gains (MQ 6)*

Four items addressing students' time on task during study preparation were available for this analysis. In the evaluation questionnaire students had answered how many learning modules they had worked through, how many hours per week they had studied, and how they estimated their overall engagement (see Table 31). The different measures of effort were weakly to moderately correlated with each other, the highest and significant correlation was between number of learning modules and overall investment of time ($r = .35$, $n = 178$, $p < .01$).

There were diverging correlations between these items and diagnostic pre-test results. Students who had invested "a lot of time" into their study preparation, for example, had obtained higher pre-test results than the rest of the sample. Students with poor pre-test results, by comparison, reported more study time per week. The variable "number of learning modules", finally, was unrelated to prior knowledge.

| How much time and effort did you invest into the study preparation? | scale |
|---|---|
| - How many weeks? | weeks |
| - How many hours per week? | hours |
| - Overall time invested | 1 (not much) to 5 (a lot) |
| - How many learning modules did you work through (1-10)? | 1-10 modules |

*Table 31 Time on task and effort-related variables*

It had been expected that time on task would be positively correlated with pre-course learning gains. The analyses suggested that indeed students who had spent more weeks / hours on learning and who had accessed more learning modules also obtained higher learning gains. Analyses of variance, however, were not significant, with large variation in each subgroup's gain scores. In particular, there was no significant effect on the "at risk" group's learning gains. The hypothesis that time on task would be positively correlated with pre-course learning gains thus was only partially supported by this study, confirming previous findings that the outcomes of such estimations produce only small effects (Kember, 2004).

##### 5.3.5.7 *Impact of the use of task strategies and help seeking on "at risk" group's learning gains (MQ 7)*

Three variables related to the use of task strategies were collected from the learning management system. The first represented how often students accessed the learning modules; the system counted each visit on a content-related page per log-in session. The second measure was the number of completed self-tests. These tests could be used for self-monitoring at the end of each module. They consisted of 10 to 15 randomised items, thus could be attempted repeatedly. The third measure was the number of questions or comments a student posted in the online forums.

| Tracking data |
| --- |
| - Number of learning module page views |
| - Number of test attempts |
| - Number of forum posts |

*Table 32 Online learning activities*

All three variables were unrelated to prior performance. According to the database query, 83% of the pre-course participants ($n$ = 603) had visited at least one learning module page (note that this analysis did not include the number of PDF downloads). Out of the existing 684 learning module pages the average student visited 240 pages (the median was 121). Students with 0-10 page views showed poorer gains than the rest of the sample, but otherwise this variable did not significantly explain achievement in the pre-course.

Similarly, the number of forum posts in the e-tutoring course was unrelated to learning gains. The e-tutoring groups were highly heterogeneous regarding communication activities and the case numbers were too small for statistical interpretation. Analysis of single cases, as well, did not suggest that a high (or low) number of forum posts could be related to achievement.

Finally, the number of self-tests per student was analysed. The highest number of test attempts was 83, but only a minority took more than ten tests. Transformed to a five-step ordinal variable, with "no test attempts", "1-5 attempts", "6-10 attempts", "11-20 attempts", and "21 and more attempts", this variable significantly differentiated between higher / lower achievement in the pre-course (see Figure 24). Students with no test attempts had the poorest learning gains (gain score = 3.8) and students with 21 and more attempts had an average gain score of 12.0 ($p < .01$).

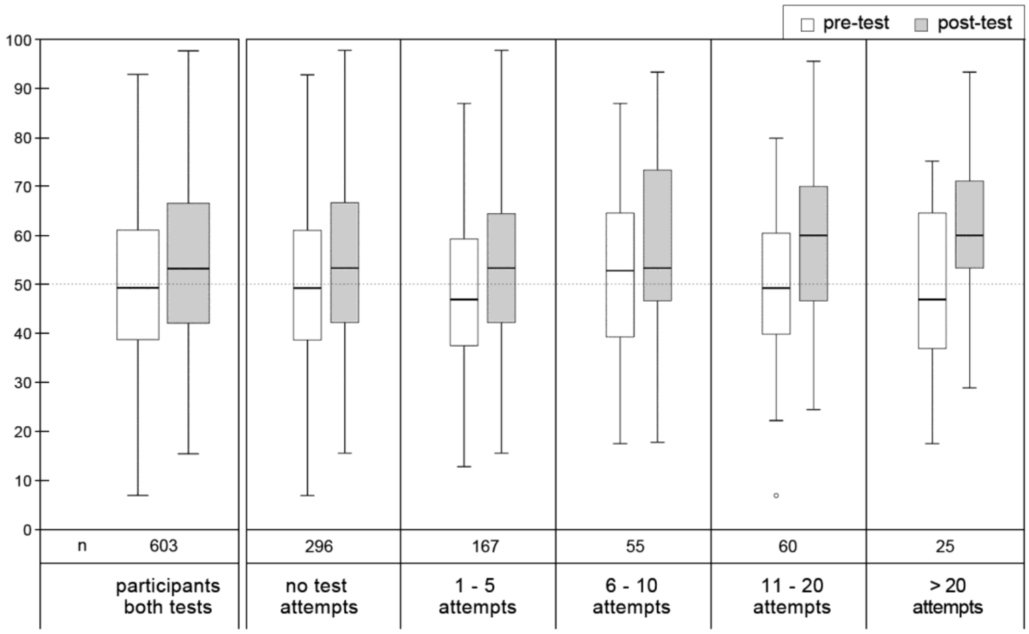



*Figure 24 Pre- and post-test results 2014 complete dataset in comparison to number of test attempts (n = 603)*

More importantly, this variable also significantly differentiated between learning gains of the "at risk" group and the rest of the sample: "at risk" students who had repeatedly taken self-tests more often improved their test results. A linear regression with the dependent variable gain score and the two predictors "risk" and "number of test attempts" was highly significant ($n = 469$; $R^2 = .01$; $R^2$ adj. $= .01$; $F$ (2, 466) = 25.460; $p < .001$). Table 33 shows the differences between clustered groups.

| | participants both tests | no test attempts | 1-5 attempts | 6-10 attempts | 11-20 attempts | ≥ 21 attempts |
|---|---|---|---|---|---|---|
| "at risk" | 8.3 | 6.7 | 8.2 | 8.2 | 12.1 | 18.7 |
| not "at risk" | 2.3 | .9 | 2.2 | 2.6 | 8.6 | 4.8 |
| total | 5.4 | 3.8 | 5.6 | 5.3 | 10.5 | 12.0 |

*Table 33 Pre-course gain score 2014: "At risk" students (n = 315) versus "not at risk" students (n = 288) and number of self-tests*

Previous research on the use of learning strategies had been inconsistent regarding the role of task strategies for achievement; some suggested no effects for either reading or rehearsal or help seeking (Credé and Phillips, 2011; Broadbent and Poon, 2015), whereas others found significant impact of web-based rehearsal (Morris *et al.*, 2005; Macfadyen and Dawson, 2010; Samson, 2015; Zacharis, 2015; Tempelaar *et al.*, 2015; Genlott and Grönlund, 2016; Ledermüller and Fallmann, 2017). These studies were supported by this thesis; the number of test attempts was the only person- or learning behaviour-related variable that significantly contributed to explaining pre-course learning gains of the "at risk" group.

#### *5.3.5.8 Impact of course type on "at risk" group's learning gains (MQ 8)*

In 2014, two additional support programmes were provided: a weeklong face-to-face course and an e-tutoring programme (see chapter 5.2.4 for details of the course design). In 2014, 42% of all pre-test participants decided to enrol in either additional programme, the remaining 68% studied alone.

| Course type | *n* |
|---|---|
| - Self-study | 399 |
| - Face-to-face | 91 |
| - E-tutoring | 85 |
| - Face-to-face plus e-tutoring | 28 |
| Total | 603 |

*Table 34 Overview of different course types 2014*

Students who participated in an additional programme had below-average pre-test results (mean score = 45.3; $n$ = 204) and an average post-test result of 50.9. In this group, pre-post-test difference was significantly affected by the type of course a student had chosen to attend. Face-to-face course participants, on average, had a gain score of 3.5 ($n$ = 91) whereas students who completed the e-tutoring course had an average gain score of 6.7 ($n$ = 85). The highest learning gains were achieved by students who had participated in both course types, e-tutoring and face-to-face, with an average gain score of 9.1 ($n$ = 28, pre-test mean score = 44.2; post-test mean score = 53.3). Figure 25 and Table 35 show the differences between pre-and post-test results. While learning gains of students in the e-tutoring course were highest, the differences between the groups were not significant (ANOVA: $df1 = 3$; $df2 = 599$; $F = 1.578$; $p = .194$).

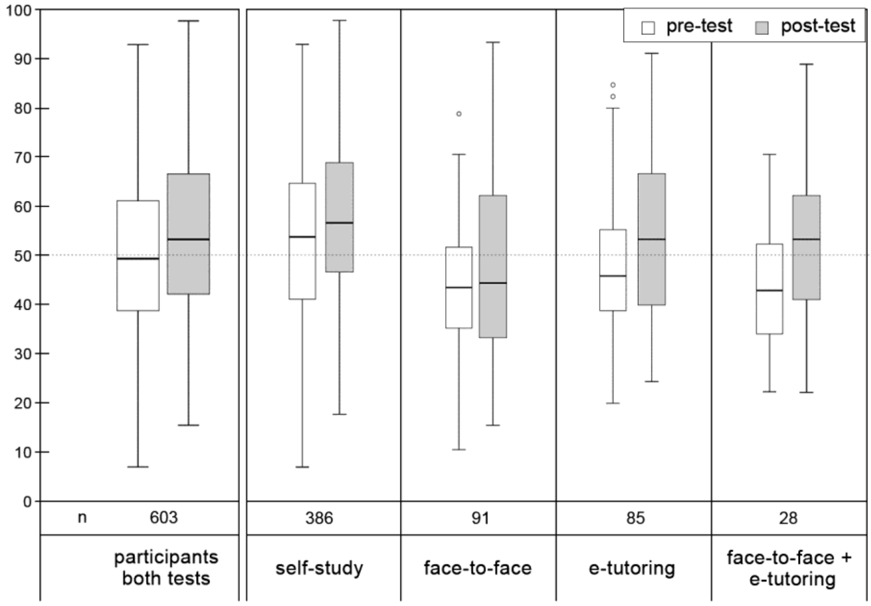



*Figure 25 Pre- and post-test results 2014: complete dataset in comparison to chosen pre-course type (n = 603)*

| | participants both tests | self-study | face-to-face | e-tutoring | face-to-face + e-tutoring |
|---|---|---|---|---|---|
| n | 603 | 386 | 91 | 85 | 28 |
| pre-test (%) | 49.7 | 52.4 | 43.6 | 47.5 | 44.2 |
| post-test (%) | 55.2 | 57.9 | 47.2 | 54.2 | 53.3 |
| gain score | 5.4 | 5.5 | 3.5 | 6.7 | 9.1 |

*Table 35 Pre- and post-test results 2014 and resulting gain score: complete dataset in comparison to chosen pre-course type (n = 603)*

When carried out with the “at risk” group, however, the ANOVA was significant (ANOVA: $df1 = 3$; $df2 = 311$; $F = 3.926$; $p < .01$). Between-group comparisons suggested significantly poorer gains for “at risk” students who had participated in the face-to-face course. The e-tutoring course accounted for an increase in gain score of 5.5 ($p < .05$). Surprisingly, the face-to-face group was also outperformed by students in the "self-study" group (plus 6.7, $p < .01$) (see Table 36).

| | participants both tests | self-study | face-to-face | e-tutoring | face-to-face + e-tutoring |
|---|---|---|---|---|---|
| "at risk" | 8.3 | 9.9 | 3.2 | 8.7 | 9.8 |
| not "at risk" | 2.3 | 1.8 | 4.2 | 3.1 | 7.4 |
| total | 5.4 | 5.4 | 3.5 | 6.7 | 9.1 |

*Table 36 Pre-course gain score 2014: "At risk" students (n = 315) versus "not at risk" students (n = 288) in the different course types*

These analyses suggested that only "at risk" students who participated in the e-tutoring course had benefitted from additional support and guidance, whereas students who had participated in a face-to-face course had not. The learning gains of "at risk" e-tutoring participants were also higher than those of e-tutoring participants who had not been identified "at risk" based on their pre-test results.

It could be hypothesised that the didactical concept of the e-tutoring course, with more online self-assessments, longer course duration, and weekly exercises with individual feedback, much more strongly affected learner engagement and thus achievement in the pre-course.

As students had self-selected into the different course types, differences in preconditions had to be accounted for, as well. In the face-to-face group, the rate of students from vocational schools was higher than in the e-tutoring course (26% vs. 15%), and final school grades on average were poorer (2.3 vs. 2.1). To some extent this effect could be related to the fact that students from the local area (Baden-Wuerttemberg or Rhineland-Palatinate) were higher represented in the face-to-face courses. The descriptive analyses had already revealed that students from federal states with longer (geographical) distance more often had a higher secondary school level and better school grades (see section 5.1), and these students also were higher represented in the e-tutoring course. Differences in gender, or age, could not be observed. The tendency of students with the highest risk to choose the face-to-face taught course might to some extent explain why the results of the self-study group, as well, were much better than those of the face-to-face group.

The major difference, however, appeared to be the face-to-face group’s lack of learning activities on the platform. Although they had been prompted by their lecturers to do so, 21% never accessed the e-learning platform. Those who did showed very little online activities and more than 50% never took an online self-test. In the group of “at risk” face-to-face students this rate was even higher (78%).

It can be concluded that the additional e-tutoring programme had the strongest effects on students’ use of task strategies on the platform. More than 70% of “at risk” students in this group did engage in the most relevant learning activity and took self-tests. This study therefore partially supported the literature that “at risk” students benefit more from guided and structured course designs (Azevedo and Cromley, 2004; Artino and Stephens, 2009), albeit the effect of course design could not be directly related to significantly higher learning gains.

#### 5.3.5.9 *Impact of mathematical problems in a "real life" context on use of learning strategies and self-reflection of the "at risk" group (MQ 9a)*

The quality of the learning process and the level of self-reflection (MQ9) could not be operationalised or measured quantitatively, it was therefore to be addressed mainly in the qualitative part of the study (see 5.3.6.6).

This also applied to the concept of "real life" applications of mathematics. However, in an approach to better understand relations between students' learning preferences and their performance level a set of items had been added to the evaluation questionnaire that explored participants' preference for different types of mathematics problems. It was hypothesised, for example, that "at risk" engineering students would prefer problems that addressed practical applications of mathematics over more theoretical ones. It was furthermore expected that students' preferences for certain problems might be related to the attitude scales.

| Looking back at the pre-course programme: what types of mathematics problems were your favourites? (multiple answers permitted) | |
|---|---|
| 1 | Problems related to everyday applications of mathematics |
| 2 | Problems related to technical applications of mathematics |
| 3 | Problems related to (my course programme) |
| 4 | Problems without any context |
| 5 | Problems related to a mathematical proof |

*Table 37 Pre-course evaluation: Application of mathematics items*

The analyses of these items in relation to prior performance, learning activities, or learning gains revealed little or no influence of the like or dislike of certain mathematics problems, with the exception of mathematical proofs. The majority of students expressed a dislike of proofs, whereas high performing students more often claimed to like them.

It was interesting that "at risk" students less often showed an interest in problems related to their course programme, but preferred everyday applications of mathematics. Otherwise, it was shown with this analysis that most "at risk" students, as well as to the rest of the sample, preferred a combination of items over practical applications only. The hypothesis that the provision of more mathematical problems related to engineering would be of particular interest for this group of students was not supported.

#### *5.3.5.10 Summary quantitative results: Impact of design on "at risk" group's learning gains and on first year performance in mathematics*

In this final section of the quantitative strand the contribution of the collected variables to the model explaining first year achievement in mathematics are summarised. The two scales, students' attitudes towards the subject as well as use of learning strategies, had been unrelated to learning gains and had shown skewed or non-linear distributions and thus were excluded from the regression analysis (Tabachnick and Fidell, 2014).

Self-reported study time as well as page view count had been only weakly or unrelated to learning gains; accordingly, these variables showed no significant effect on Mathematics I. The course type a student participated in had significantly affected pre-course learning gains of the "at risk" group; however, this variable could not be related to a significant increase in Mathematics I performance. As mainly students with a relatively poor pre-test result had participated in an additional course the impact of this variable was apparently not strong enough to overpower the dominant role of prior knowledge. Only one of the collected variables, the number of pre-course test attempts, showed a significant influence on Mathematics I.

Table 38 gives a summary of the changes in variance explained when pre-course gain score (Model C) and number of test attempts (Model D) were added. Even if the increase of effect of Model D was relatively small it was an important outcome that the number of test attempts was still significant in the Mathematics I examination which was taken several months after the pre-course. According to this model, a student who had taken ten self-tests in the pre-course, for example, was predicted an increase in Mathematics I performance of .2.

| | Model B | | | Model C | | | Model D | | |
|---|---|---|---|---|---|---|---|---|---|
| | *B* | *SE B* | β | *B* | *SE B* | β | *B* | *SE B* | β |
| 1 Gender | .14 | .12 | .05 | .17 | .12 | .06 | .13 | .12 | .05 |
| 2 Age | .03 | .05 | .06 | .05 | .04 | .09 | .04 | .04 | .07 |
| 3 Gap school / university | -.04 | .06 | -.04 | -.07 | .06 | -.08 | -.08 | .06 | -.10 |
| 4 Fed. state[a]: R-P | .08 | .11 | .04 | .05 | .11 | .02 | .03 | .11 | .01 |
| 4 Fed. state[a]: Hesse | -.02 | .11 | -.01 | -.05 | .11 | -.02 | -.06 | .11 | -.03 |
| 4 Fed. state[a]: NRW | -.05 | .14 | -.02 | -.07 | .14 | -.02 | -.12 | .14 | -.04 |
| 4 Fed. state[a]: Bavaria | .47 | .15 | .14** | .37 | .15 | .11* | .26 | .15 | .08 |
| 5 Type of school[b]: S-GYM | -.10 | .17 | -.04 | -.10 | .16 | -.04 | -.15 | .16 | -.05 |
| 5 Type of school[b]: G-GYM | .19 | .16 | .09 | .13 | .16 | .06 | .09 | .16 | .04 |
| 6 Math. grades[c]: good | .16 | .11 | .08 | .17 | .11 | .08 | .13 | .11 | .07 |
| 6 Math. grades[c]: very good | .00 | .15 | .00 | -.06 | .14 | -.02 | -.08 | .14 | -.04 |
| 7 Secondary school GPA | .44 | .10 | .23** | .38 | .10 | .20** | .38 | .10 | .20** |
| Diagnostic pre-test score (%) | .03 | .00 | .40** | .03 | .00 | .49** | .03 | .00 | .46** |
| Gain score (%) | | | | .01 | .00 | .18** | .01 | .00 | .16** |
| Number of test attempts | | | | | | | .02 | .01 | .11* |
| $R^2$ / $R^2$ adj. | .33 (.31) | | | .35 (.33) | | | .36 (.33) | | |
| *F* for change in $R^2$ | 16.67** | | | 17.47** | | | 15.32** | | |
| Durbin-Watson statistics | 2.009 | | | 2.001 | | | 2.017 | | |

*B*: unstandardised regression coefficient; *SE B*: standard error; β: standardised regression coefficient; significance levels: *p < .05; **p < .01

[a]Federal state Baden-Wuerttemberg = baseline; [b]Vocational school = baseline versus S-GYM (subject-related Gymnasium) and G-GYM (Gymnasium); [c]Math. grades poor = baseline

*Table 38 Hierarchical regression analysis for variables predicting Mathematics I (n = 465). Model B: students' preconditions when entering university versus Model C gain score added, Model D number of test attempts added*

Summarising, the quantitative analyses supported the hypotheses that basic knowledge in mathematics was predictive of first year mathematics performance of engineering students at DHBW Mannheim, as well as of overall study success. The significant influence of pre-course participation and pre-course gain score on these relations suggested that the course indeed supported "at risk" students' transition to tertiary education. At the same time the analyses did not show that "at risk" students benefitted more from the course than high performing students; the gap between these groups thus could not be closed by pre-course participation.

It could be shown, however, that the effect of poor basic knowledge in mathematics on first year performance in mathematics could be moderated by the following variables:

(1) *Pre-course participation.* Students who participated in the diagnostic pre-test or the pre-course outperformed students who did not. Note that the self-selection bias had to be accounted for; it is suggested that *avoiding* the diagnostic pre-test or the pre-course could be a risk factor in its own right.

(2) *Learning gains in the pre-course,* measured by the difference between pre- and post-test results.

(3) *Self-monitoring and rehearsal,* measured by the number of self-tests a student submitted.

### 5.3.6 Qualitative results

Before addressing the sub-research questions a description of the setting and a short summary of participants' accounts of their first year mathematics learning experience are given.

The pseudonyms used for the interviewees were Anna, Ben, Chris, Daniel, Eric, Frederic, Julia, Marc and Nora. The appendix G.2 provides a profile of each student. Four students had participated in the e-tutoring course [Anna, Ben, Marc, Nora], one had also taken the face-to-face course [Anna] and five students had studied alone. The average pre-test mean score of the nine interviewees was 43.5 (min: 27.1; max: 49.5) and their average post-test mean score was 57.0 (min: 26.7; max: 75.6). The average improvement thus was 13.5, indicating that these students were in the upper half of the "at risk" group and that they also had above-average learning gains (average gain score in the "at risk" group had been plus 8). There was, however, a large variance in the gain score, ranging from minus 20.4 to plus 34.4.

When the interviews took place all students had participated in the first year exam Mathematics I. It should be noted that all interviewees showed a strong focus on exam dates, grades and scores when referring to their first year experience. To some extent this behaviour could be related to the fact that four students had failed their first attempt in Mathematics I (one student later also failed the second attempt and thus had to take an oral examination). It also confirms previous research that engineering students in general show a higher performance orientation (Meyer and Eley, 1999; Litzinger *et al.*, 2011; Gainsburg, 2015).

In further alignment with the literature all interview participants described the first year workload as very high. For all of them the first weeks and months had been some sort of shock, and, compared to secondary school, they considered mathematics as much more difficult and that they had to invest much more time into their learning.

> "Well, in school, especially in maths, it was enough for me personally to pay attention, to participate in class. And yes, maybe I had to look at one, two things again, about formulas or something. But I NEVER had to do a lot more work at home; it was sufficient, but it is definitely not sufficient here." [Eric]

> “What we did in two years at school that’s what we did here in one semester (laughs). Well, it’s the difficulty AND the quantity, all those things that you have to learn.” [Julia]

> “In the first semester I made the mistake, the fatal mistake, that I thought: ‘yes, we have some time off between the years anyway, I can start then because the exams aren’t until the end of January’, you know, like for the *Abitur* [final secondary school exams], and then you kind of notice ... there isn’t enough time, especially not for four subjects like maths, logics and digital technology and what was it again? web engineering.” [Ben]

The next section gives an overview of the interviewees’ views on the relevance of the pre-course for their degree programme.

#### *5.3.6.1 Relation between prior knowledge in mathematics, pre-course participation, and study success in engineering (summary of MQ1 to MQ3)*

The first part of the quantitative analyses had resulted in a model demonstrating basic knowledge in mathematics as a significant predictor of first year performance in mathematics (MQ2), which in return was a significant predictor of engineering study success (MQ1). Participation in the pre-course had shown a moderating effect on this relation and this effect was increased by a high pre-course gain score (MQ3).

The qualitative part of the study was to show if students’ perceptions of the role of mathematics for their degree programme were in alignment with these observations. In the interviews they were asked why they had chosen to study engineering and if mathematics had been relevant for their decision. While engineering of course was all participants’ main study interest, they all appeared to be well aware of the relevance of mathematics for this degree programme. It was remarkable that all interviewees had been good or very good at mathematics at secondary school; two had attended A-level courses (*Leistungskurs*) [Frederic and Julia]. This discrepancy might explain the relatively weak influence of mathematics school grades in the multiple model explaining first year performance.

Referring to their first weeks at university all students were concerned about the pace and difficulty level at which mathematics was taught, confirming the literature that the first months at university come as a shock to many students (Liston and O'Donoghue, 2007; Croft *et al.*, 2009; Harris *et al.*, 2015; Rach and Heinze, 2017).

They were also unanimous regarding the role of basic skills for being able to cope with these demands.

> "It's important to understand every single step of a calculation so that you can understand everything easily during the lecture." [Frederic]

> "The basics in maths, those aren't highly complicated calculations. You have to be able to solve them quickly and not ponder for three hours." [Nora]

> "I would say, this basic knowledge is getting more and more important, kind of, the longer we're studying." [Daniel]

When asked which learning contents had been particularly helpful for their first months at university nearly all students named trigonometry. This came as a surprise as the author (and the *optes* team) had expected trigonometry to be the one topic that might be less relevant for computer science students and thus could be removed from their pre-course syllabus. Other topics were logarithms [Daniel] and geometry [Marc]. Some students were able to remember details from the pre-course that had been useful; Anna, for example, referred to polynomial division and Julia remembered needing a pre-course content in her mathematics lecture:

> Julia: "Many pre-course contents were useful later and I thought 'oh, thank goodness I repeated that'."
> Interviewer: "Can you name an example?"
> Julia: "There was this lecture in maths where I noticed that ... Wait, it was prime ... some isation."
> Interviewer: "Prime factorisation?"
> Julia: "Exactly. Because then I thought, goodness, where could you possibly need that? And then it was needed in this proof and I was quite happy that I had done that."

In hindsight, all participants considered participation in the pre-course as relevant for their course.

> "Yes, it was pretty helpful, that you could find out, yeah, okay, that's where you're lacking a bit of knowledge. Otherwise I would have walked right into the first lecture and would have been struck dead. And with that course, it wasn't so bad." [Ben]

> "And if I hadn't taken part in this pre-course I would have thought: 'Why was he able to just leave out the brackets there?' Because that part isn't explained any more. And that's why [...] it really did help." [Frederic]

These outcomes should not be overemphasised as students who found the course *not* helpful were probably less likely to participate in the interviews. But the positive comments indicated that students themselves felt the need to consolidate their school knowledge, even if they just had left secondary school. Only one student [Marc] thought that the pre-course curriculum had been a little too voluminous and intimidating compared to the first year demands in mathematics.

The qualitative analysis thus was in agreement with the quantitative results that basic knowledge in mathematics was highly relevant for the transition to tertiary education. Participation in the pre-course did show a positive effect on participants' first year experience. The overall high acceptance of the pre-course confirmed observations made in the cross-institutional survey by Bargel (2015) that additional mathematics support is strongly needed and welcomed by many students entering tertiary education.

#### *5.3.6.2 Impact of attitude on "at risk" group's learning gains (MQ 4)*

The quantitative results had suggested a correlation between prior knowledge in mathematics and students' attitudes, but there also had been rather skewed distributions, with only a small group of students disliking mathematics or feeling very unconfident. None of the interviewees appeared to be in this group: all claimed to have liked mathematics at school. For one [Eric] mathematics had been the favourite subject. Based on their secondary performance, all interviewees had felt quite self-confident regarding their mathematics ability. It may be hypothesised how strong these positive answers were influenced by social desirability, but students' accounts of their secondary school experience suggested that these indeed had been positive. Thus attitude towards mathematics was probably not a factor influencing their participation in the pre-course.

During the first months at university, however, some students' attitudes towards the subject had already changed. When asked about the difference between their learning experience at secondary school and at university Eric and Frederic, in particular, appeared to feel uncomfortable with the more abstract and complex way of doing mathematics.

> "In school you could do much more ... it was a little bit easier to understand. It was easier, of course, but it was also, I'd say, always related to doing problems and exercises, and this here is rather dry." [Frederic]

Interviewer: “What was it that you liked better about maths at school?”
Eric: “Well, basically, you kind of get a problem and then you try to solve it, logically, using some formula, then rearranging or equating, and that’s it.”

These students perceived a fundamental difference between mathematics at secondary school (which they had liked) and the way mathematics was taught at university.

#### 5.3.6.3 *Impact of time management, organisational strategies and time on task on “at risk” group’s learning gains (MQ 5 to MQ6)*

The quantitative analyses had not shown any effects of the use of time management or organisational strategies on “at risk” students’ learning gains. In the interviews it emerged that for most participants it was difficult to describe how they had structured and managed the learning process during the pre-course, or how they did so at university. When asked about personal schedules students usually referred to their lack of time. It also became apparent that there were broad differences in their investment of time and effort. It therefore seemed reasonable to summarise the qualitative results related to time management (MQ5) and time on task (MQ6) together.

Anna, for example, had been very determined to improve her basic knowledge and to be perfectly prepared for her computer science course. She was aware of her need to refresh her basic knowledge in mathematics and thus participated in both additional programmes. She also took private lessons. Anne worked through eight of the ten learning modules (four were part of the e-tutoring course) and appeared to be able to organise her learning quite effectively. The other e-tutoring participants [Ben, Marc, Nora] had chosen this course because it had been suggested by their employers. They adopted the schedule provided by the course, which meant to work through four learning modules (one per week) and to upload an exercise sheet by the end of each week. The quantitative analyses had shown that e-tutoring students were more likely to be active e-learning participants; the qualitative investigation confirmed these results. The e-tutoring participants spent more time on task (between 10 and

15 hours per week over a period of four weeks) and submitted between four and five online self-tests (in addition to the weekly uploads named before).

> "Well, at the beginning of the week I looked at the tasks and exercises for this week and I did the ones I considered easy. And midweek I did the more difficult ones, or at least started doing them. And Saturday, Sunday the most difficult ones. Tried to solve them somehow, and then often the cry for help, hey, do you have an idea how to do this, can you give me a hint, ... yeah, that was the usual procedure." [Nora]

The five students who learned alone were quite diverse regarding their approaches and the intensity of their learning. Frederic, for example, worked through all ten learning modules and submitted 13 self-tests. He had worked out a weekly schedule and found it sometimes difficult to stick to it, but had the overall feeling that his approach had been successful (his gain score had been plus 34).

> Frederic: "I went through all of them."
> Interviewer: "And how long did it take you to do that?"
> Frederic: "That was really A LOT of time. If you really do all problems, take all tests, then you'll need half a week for each module, minimum. If you work on it every day ... I tried, like, to do a certain section each day and then, let's say to complete one learning module in one week." [Frederic]

Chris, by comparison, had not felt the need for time management in the pre-course. He studied "an hour here, an hour there", resulting in "one day altogether". The other students found it hard to remember how much they had learned and suggested overall durations between ten [Daniel] and fifteen hours [Julia]. Their statements also indicated that they felt they might have done more.

> "I think the course was available early enough and if you really WANT to do something you will probably find time for it. You just have to include it in your planning." [Daniel]

> "If you had REALLY worked through it, well, I only skimmed the material, you would have been really well prepared." [Julia]

The outcomes of the interviews suggest that indeed the use of time management and organisational strategies had only played a role for two students who had worked through the complete pre-course curriculum. The e-tutoring participants had mainly relied on the schedule provided by the course. The rest of the group seemed to have taken the course less seriously, and probably just stopped learning if they felt overburdened.

The interviews thus confirmed the quantitative observations that the previously reported good predictive quality of time management and organisational strategies scales may not be transferable to preparatory courses in mathematics.

#### 5.3.6.4 *Impact of the use of task strategies and help seeking on "at risk" group's learning gains (MQ 7)*

In the interviews students were asked to describe how they had studied with the pre-course. The usual approach had been to test their knowledge with a self-test or exercise and, if they failed the test, turn to the learning modules or search the internet. Thus doing problems appeared to be the most preferred strategy to both consolidate knowledge and to monitor learning, supporting the relevance of self-tests that had been observed in the quantitative analyses.

Most interviewees found it difficult to describe how they learned and what metacognitive strategies they used. Expressions like learning, rehearsal, or doing problems were used interchangeably, suggesting that mathematics learning to them was equivalent to doing problems. This also applied to their first year at university; students' learning strategies were mainly characterised by submitting the exercise sheets provided by their lecturer. Two students reported to use flash cards for learning definitions [Daniel, Frederic]. One student looked for additional literature at the library [Chris], whereas the others stated that they would use Google and YouTube if they were lost.

In the e-tutoring course, some participants had asked peers or tutors for help, but no interviewee had used the forum. The favourite communication channels appeared to have been WhatsApp and E-mail and thus were not tracked by the system.

> "And I didn't write anything in the forum and hardly any of us ... did either. I mean, you don't know who you are writing to and then the tutor might think, eh, 'how stupid are they and what are they talking about?'" [Nora]

Obviously many students had felt intimidated by publicly asking content-related questions, which might explain the poor relevance of forum posts for learning outcomes observed in the quantitative part of this study.

Most students appeared to have worked through the pre-course by doing self-tests, and then searching for more information within the programme or on the internet. In the quantitative evaluations some learners also reported to have used textbooks. At university, however, the role of help seeking and group work emerged as a much more important strategy; these results will be reported in section 5.3.6.8.

#### *5.3.6.5 Impact of course type on "at risk" group's learning gains (MQ 8)*

The quantitative analyses had already indicated that the more structured design of the e-tutoring course positively affected students' activity level and was much more efficient than the shorter and less guided face-to-face courses that had not demanded the submission of course work.

> "... because, you only got a certificate after submitting all exercise sheets. And I thought that was quite all right because you were somehow forced to do some problems. Because, in hindsight I guess they do help, even if you're not always in the mood to do them." [Ben]

> "I did two courses, one e-tutoring course and one in-class. And I was surprised, because I liked the online course better and I gained much more from it. It depends, of course, on the tutor and on the group, but the online course was much more focused on rehearsal. You had to submit something every week but you also had enough time to answer the problems. And when you were ready and uploaded your answers you immediately got feedback. ... And if you were stuck you could ask the tutor and he would answer rapidly. In the face-to-face course everything was explained by the lecturer but there was no homework ... In retrospect I would say that the online course helped me more than the face-to-face course. Despite that, I'm happy that I did both." [Anna]

It was particularly interesting that learners appreciated the demand to upload coursework. The certificates that were handed out at the end of the course only attested attendance and were irrelevant for their degrees; students thus were not obliged to "pass" the course. In some cases the companies appeared to be the main drivers as they had allowed students to study mathematics while on internships and thus asked them to present their certificates at the end of the course. Concluding, the interview outcomes suggested that most "at risk" students showed only low levels of self-regulation and thus had benefitted from the higher level of guidance and structuring provided by the e-tutoring course.

#### *5.3.6.6 Impact of system-based guidance on use of learning strategies and self-reflection of the "at risk" group (MQ 9)*

In the final sub-research question it was explored if and how the formative e-assessment concept did support the self-regulated learning process. One presumption had been that the diagnostic self-test would raise students' awareness of the relevance of basic skills in mathematics and help them "calibrate" their own knowledge. The interviews indeed suggested that the diagnostic test had such an effect.

> "Yes, well I, like I said, I was actually really happy that this even exists. And that you get this preparation. It somehow reinforces this feeling that it is getting a bit more serious in mathematics. Because, from the beginning, the first thing I understood was 'Please have good grades in maths. If you don't have good grades, prepare yourself REALLY well.' and so on. Then there came the whole thing with the first test and the pre-course, then the second test and so on. And then I thought, ok, this does seem to be a bit more serious." [Julia]

The diagnostic feedback and the learning recommendations were considered helpful by all interviewees. Some had already been aware of their deficits and were grateful for a confirmation.

> "Well, I actually always think it's good if you have one of those tests so you can just check and see how you're doing and it doesn't count or something ... I mean, I kind of already knew that I am weak in trigonometry, but it became really evident that it is my worst subject. Some other things were pretty good, well, quite good I'd say, and then trigonometry was somewhere at the lower end of the range. It was quite good to see how bad it really is, I'd say." [Nora]

Others related their test results to the fact that they had forgotten many secondary school contents. One significant difference was how students felt about their (weak) mean scores. Based on their previous mathematics performance at school none of the interviewees had considered themselves to be in the "at risk" group; three students in particular [Daniel, Frederic, Marc] were quite unsettled after they had performed poorly in the pre-test.

> "When we got the results, I can't remember the percentages, but I was actually surprised in a negative way, that my results were relatively bad, because I came straight from school and also had a very good leaving certificate and then I took the entry test and then I just stood there and thought, wow, where is this heading to." [Marc]

All three showed a relatively strong focus on their scores in the post-test and thus were either contented that they had improved [Frederic, Marc] or concerned that they had not [Daniel].

> "And in the pre-test I think I wasn't THAT good, I only had 40% or so. And then I just, until it really got started, up to then I just did all of the exercises. There was always a test after every exercise and then I just went through everything, and always solved all of the problems. And then there was this post-test again, here at the university and then I even managed to get 75%." [Frederic]

> "It was different in this test here [the post-test]. There were some topics, which I am actually good at, where I performed pretty badly. Now I don't know if this was because of being nervous or something. Yes, the test results were worse than I expected them to be." [Daniel]

Thus the pre-post-test design had obviously evoked, or at least reinforced, a performance orientation in these students. Chris, by comparison, stated to have been unimpressed by his very poor results in both tests.

> "I was quite surprised [that there was a post-test], but okay. When I saw it doesn't count and isn't relevant for entering university or anything I said 'Ok, no problem.'" [Chris]

#### *5.3.6.7 Impact of mathematical problems in a "real life" context on use of learning strategies and self-reflection of the "at risk" group (MQ 9a)*

Another hypothesis had been that the practical examples provided in the pre-course would help students to relate knowledge and to reflect on the relevance of mathematics for their course. The interviews suggested that some of these examples had indeed been helpful for students and that they had liked the interactive elements and animations.

> "For example, the typical exercise with the acceleration of a vehicle, well, that is more fun than just calculating it on a piece of paper, instead you can imagine it visually and there is a connection to something real." [Marc]

> "Yes, well, ... these physics-related things ... I also had A level physics, that's why I partially already knew about it and the different formulas or different forces and things like that. And I thought that was good. Well, it was nice to look at, I'd say, or good to imagine it. Well, I thought it was very well done." [Frederic]

> "I'd say this practical approach was the best and it's much more interesting than if you have a theoretical question. And it does not matter if its computer science or any other application. What's important is that you have an example, that you can imagine what it's used for." [Daniel]

It seemed that practical examples were welcomed in particular when students already had some existing knowledge, about physics or mechanics that they could relate to. The interviews also suggested that not all “real life” examples had been found relevant by learners.

> “Well, I must say, some were quite helpful, you could imagine what you COULD use it for. Some other exercises were like, I thought: (laughs) ‘Do you really calculate it like this in real life?’ and ‘there are probably easier ways to calculate this’, but sure, it’s probably not that easy to find word problems that fit ...” [Ben]

One unexpected outcome was that two students [Anna, Chris] found it much more difficult to understand the much longer texts in “real life” problems.

> “For me it’s probably more difficult than for other students because I didn’t go to secondary school in Germany. I always need to re-read the problem and make sure I understand what it’s all about (laughs). Which is why I hate it if there’s a time limit in a test or something because I really need much more time for such problems.” [Anna]

The quantitative evaluation had already suggested that most students liked a combination of different problems and exercises; the qualitative analysis did not add much additional information. The provision of practical examples was welcomed by learners but considering the time needed to answer them, they were also interested in more simple tasks.

##### *5.3.6.8 Differences between learners and impact of social interaction on self-reflection of the “at risk” group*

So far, the evaluations had not suggested strong effects of human or system-based guidance and support on students’ self-regulation abilities. It indeed seemed that practice and rehearsal had been paramount for pre-course participation and that maybe the pre-course should not be overburdened with meta-cognitive goals and observations. At the same time, the group of interviewees’ first year performance in mathematics showed two extreme deviations from the model predictions.

One student with very poor pre- and post-test results showed a very good performance in Mathematics I. In the interview it became apparent that this person was very interested in complex mathematical problems and actually liked mathematical proofs (and was the only student who looked for additional literature at the library). Despite the poor pre-and post-test results this student was quite self-confident regarding basic skills in mathematics, The biggest problem in the transition phase was not mathematics but following lectures in other subjects because of language issues.

Another student who had learned intensively throughout the pre-course and achieved a very impressive gain score struggled extremely in the first year at university and failed not only Mathematics I but another exam that also demanded a high amount of mathematics. This deviation could not be explained by external factors like language, demographics, or educational background.

This qualitative analysis will be concluded with an attempt to understand this personally very disappointing result and to identify differences between learners in the transition phase that might need to be considered for the design of preparatory courses.

All students expressed a preference for doing problems as a task strategy to learn mathematics, but there were fundamental differences in their engagement in study groups during first year. Some students participated in several study groups and in their statements it became apparent that learning with peers had a positive impact on their understanding of mathematics.

> "Studying in groups is what helps me the most, solving all kinds of problems, and talking it through with somebody, discuss it." [Anna]

> "Sometimes it does help, if you don't understand something and you can't find a proper solution, just to ask somebody else whether they can explain it in their own words." [Ben]

> "Well, mostly I prefer studying on my own. But especially in maths I find it makes sense to study in groups. There will always be one person knowing something the others don't. And then the next person gets an idea the others would NEVER have. Yes, I really do think it helps." [Julia]

Other interviewees disliked participating in study groups because they were used to learning alone and did not want to be slowed down, a view on group learning that has been reported mainly for high performing students (Gasiewski *et al.*, 2012).

> “Well, personally I am the type who mostly studies on his own. Sure, you talk to a fellow student, but usually I do everything by myself, except if I really have a question. Or I’ll answer somebody else’s question, and then sometimes you might sit together and talk about it.” [Marc]

A third group appeared to dislike study groups and only chose to participate in one after having failed an exam.

> “Not for maths at the moment. In logics, because I have to take the oral exam, we now have a small study group, but not yet for maths, no. Maybe there will soon be another group, because the analysis exams are at the end of June.” [Frederic]

For these students participating in a study group meant admitting that they had a performance problem but they did not consider peer learning as a positive learning experience. There also were differences in students’ ability to benefit from group learning; some found it difficult to organise the process effectively and to really help each other.

> “Well, in general mostly alone, because I can concentrate better, because especially when I study in a group, I have often experienced that you easily let yourself be distracted, stray away and then in the end you have been sitting there for four hours and have hardly learnt anything.” [Ben]

It also was striking that not one of the students who failed Mathematics I sought help from their lecturers or employers. Several interviewees reported that their companies offered different kinds of supervision but that they did not feel the need to ask for support.

Thus after having been quite unremarkable in the pre-course evaluation, the role of social environment emerged as a highly relevant factor for a successful transition phase. It seemed that some students found it difficult to give up learning strategies they had found effective at secondary school (and during the pre-course) that now no longer were sufficient. Particularly students who had been good at mathematics at secondary school and now struggled at university appeared to feel the “disenchantment” more strongly and found it more difficult to adapt to the new learning environment:

> Frederic: “Before [in school] it was all really logical, just answering problems. Because these were, I would say, normal maths problems. But here, it’s all different and you have to do these proofs.”
> Interviewer: “Mhm. And did you like that more, simply doing problems?”
> Frederic: “Yes. Sure.”

This also affected their ability, or willingness, to relate knowledge and to reflect on its relevance for their course.

> Interviewer: "And now, if you compare school and university, where did you find it easier to see what you need mathematics for?"
> Eric: "Definitely at school."

Actively engaging in study groups may have helped students to overcome these difficulties. It also emerged that social contacts outside university helped students to relate knowledge and to acknowledge the relevance of mathematics:

> "Because I asked around in my company a bit, or told them "Okay, we did this and this in maths. And this and that", and then they said right away: "Sure, we did that, we know that, and sometimes we need it." So, it still seems to be relevant. And if people have been out of university for 30 years and they still remember it, they obviously need it now and again." [Julia]

# 6 Summary and discussion

## 6.1 Summary

The results of this study demonstrated how variables related to the learning process in a web-based pre-course in mathematics interact with each other and how these interactions are influential for a meaningful evaluation. Only some variables emerged as significant for an improved first year performance of the group of “at risk” students, for example learning gains in the pre-course and the number of self-test attempts, whereas others showed unexpectedly weak effects, for example attitude towards the subject or the use of time management and organisational learning strategies.

The basis for all analyses were the two presumptions that (1) a lack of basic mathematics skills indeed was a risk factor regarding the completion of a degree programme and that (2) preparatory courses in mathematics had the potential to reduce this risk.

The first presumption was confirmed with statistical analysis of first and final year performance of three complete cohorts of engineering students at DHBW Mannheim (sub-research questions MQ1). Compared to other first year performance measures the exam Mathematics I was identified as the most significant indicator of study success at the end of the degree programme.

In a multiple linear regression with Mathematics I as the dependent variable, students’ mean score in the diagnostic pre-test was found the strongest determinant of first year mathematics performance. Accordingly, a pre-test mean score below 50% was defined as a risk factor regarding first year achievement. By comparing the effect of pre-test results to other known predictors this study contributed to the body of research on the role of prior knowledge in mathematics for study success in engineering. Regarding the consistency with previous literature (Zhang *et al.*, 2004; Henn and Polaczek, 2007; Ehrenberg, 2010; Faulkner *et al.*, 2010; Carr *et al.*, 2013; Abel and Weber, 2014; Greefrath *et al.*, 2016) these results also established the validity of the chosen pre-test design.

The second presumption that mathematics pre-courses have a moderating effect on the strong influence of prior domain knowledge could be confirmed, as well. When added to the multiple linear regression, the gain score (pre-post-test difference) could be related to a significant increase in Mathematics I results, suggesting that an increase in basic knowledge had made it easier for students to master the first year demands in mathematics. It needs to be stated, though, that this effect was not very strong. In particular, the hypothesis that the positive effect would be stronger for the group of “at risk” students was not confirmed.

Based on the framework of self-regulated learning, hypotheses about the relevance of prior knowledge, attitudes, learning behaviour, and environment for pre-course learning gains were tested with a focus on the “at risk” group. Figure 26 shows and overview of these results. Person-related variables (prior domain knowledge in correlation with metaknowledge) remained the strongest predictors of first year performance and of overall study success. If higher performing students participated in the pre-course these pre-conditions also positively affected their use of learning strategies and it was also found that this group of students more often chose to participate in the e-tutoring course.

For the group of “at risk” students the strongest moderating factor in this model was related to learning behaviour: an increase in self-tests was the most significant driver of an increased gain score and an improved first year performance in mathematics.

The expected influence of course design in form of additional support was weaker than expected: while “at risk” participants in the e-tutored course benefitted more than those who participated in the face-to-face course, they did not outperform the self-study group. Course design did, however, impact students’ learning behaviour and thus indirectly affected the gain score: e-tutoring students more often engaged in self-assessment and spent more time learning.

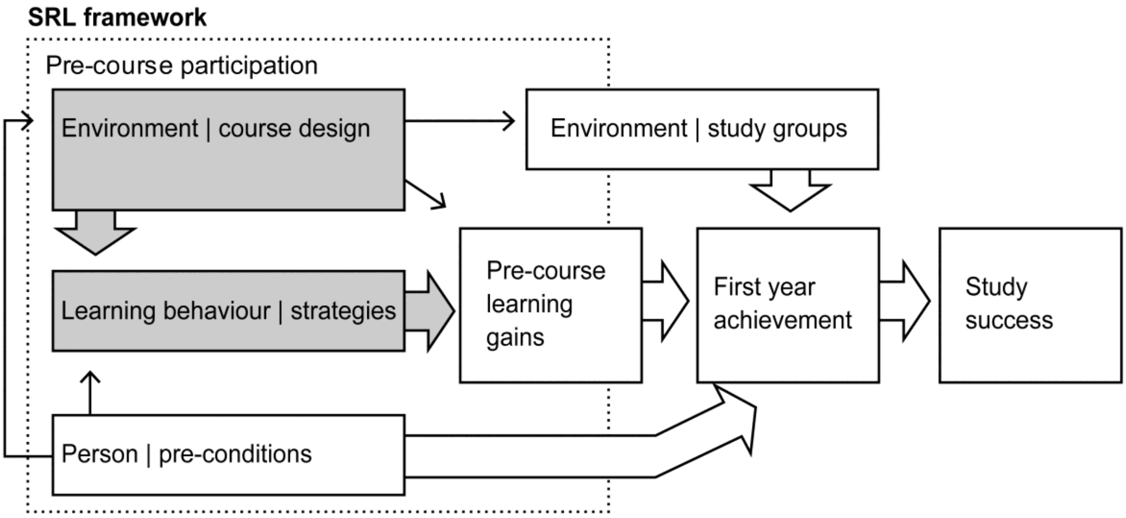



*Figure 26 Conceptual framework: effects of pre-course participation on "at risk" students' first year performance, summary of study outcomes*

Figure 26 also shows the additional environment-related factor that emerged in the qualitative analyses: participation in study groups was found highly relevant for mastering the first weeks and months at university. Students who engaged in discussions with others about mathematics also found it easier to adapt to the unfamiliar and sometimes frustrating first year learning environment. For pre-course outcomes, however, group learning was not found relevant.

The hypothesis that the provision of problems related to the application of mathematics would result in an increased learner engagement had to be rejected. In the pre-study the demand for "real life" examples had been uttered repeatedly by students; a lot of effort had been put into the design of such mathematics problems, often enhanced with animations and interactive content. The quantitative analyses suggested, however, that the majority of pre-course participants preferred a combination of different types of problems and that these preferences were unrelated to activity level or any performance measures. The only significant result was that high performing students more often preferred abstract problems and mathematical proofs, which were clearly disliked by the rest of the sample. The qualitative analyses suggested that "at risk" students appreciated relations to technical applications but also dreaded the higher amount of time needed to answer them, particularly if there were language issues.

## 6.2 Discussion

By investigating influential factors regarding mathematics learning in the understudied context of university pre-courses this study fills a gap in the literature and contributes to understanding how web-based preparatory courses can support students in the “liminal phase” between secondary and tertiary education (Clark and Lovric, 2008). The theoretical model of self-regulated learning provided the framework to comprehensively evaluate the effects of participation in a web-based course on learning outcomes. By collecting data related to the individual, their learning behaviour, and the learning environment this study could build upon a large body of existing research (Zimmerman, 1989a; Boekaerts *et al.*, 2000; Hacker, 2009). It contributed to the literature by focusing on a specific group of learners (“at risk” students) in a particular period of time (before entering university).

Based on these analyses it is suggested that for successful learning processes of “at risk” students other variables and data sets are relevant than for students with a sound level of prior knowledge. Making use of time management and organisational strategies, for example, has been suggested as a reliable predictor that adds to explaining tertiary performance (Weinstein *et al.*, 1988b; Carson, 2011; Broadbent and Poon, 2015). In this study, however, such strategy use was found a characteristic of high performing students only, whereas for the rest of the cohort the scales produced inconsistent results (see also methodological discussion). It is argued with Eley and Meyer (2004), as well as Martin (2012), that an analysis of organisational strategies is mainly relevant to identify “ideal” learners.

“At risk” students who chose to participate in a course that provided “external” structuring, however, appeared to benefit from this choice. It is suggested that a weekly schedule in combination with a more binding character led to the higher learning gains of e-tutoring participants in comparison to the face-to-face group. Such an interpretation is in alignment with literature on “at risk” students’ learning behaviour and their need for additional guidance (Plant *et al.*, 2005; Artino and Stephens, 2009; Michinov *et al.*, 2011). The design also showed a significant impact on the number of online learning activities; e-tutoring participants spent more time online and more often engaged in self-assessment. With Greene and Azevedo (2007) it is argued that the e-tutoring course helped students concentrate on the learning contents and relieved them of cognitive load.

As stated before, the best predictor of pre-course learning gains was an active engagement in self-tests. The number of test attempts outperformed other measures like time online, number of page views, or clicks. Considering the methodological difficulties to quantify effort or time on task these results contributed to research on self-regulation in web-based environments (Morris *et al.*, 2005; Macfadyen and Dawson, 2010; Samson, 2015; Zacharis, 2015; Tempelaar *et al.*, 2015; Ledermüller and Fallmann, 2017). Theoretically, they could be interpreted from different perspectives:

First, doing self-tests could be interpreted as a measurement of effort. Students with broad knowledge gaps logically need to invest a lot of time and effort into closing these gaps and "at risk" students who don't will not show an increase in gain score (Kember *et al.*, 1996; Kolari *et al.*, 2006; Plant *et al.*, 2005). For the case of a web-based pre-course in mathematics, the number of test attempts was the best indicator of such an effort when compared to other measures. The interviews suggested a high preference for doing problems over other mathematics learning activities, so that this task strategy logically played the most significant role for a successful pre-course participation.

Second, task strategies like rehearsal and repetition have been found of particular relevance for the acquisition of basic skills. The significant role of self-test attempts thus might be ascribed to the fact that many students were able to re-activate and consolidate this basic knowledge by taking many tests (Armstrong and Croft, 1999; Ballard and Johnson, 2004). From this perspective, rehearsal helped students to apply mathematical rules confidently and thus enabled them to meet the demands of the transition to university (Meyer, 2000).

Third, taking self-tests is also a way of monitoring and evaluating the outcomes of the learning process (Winne, 2004; Zimmerman and Moylan, 2009). Only students who tested their knowledge were also confronted with still existing knowledge gaps and then needed to decide if and how to address these gaps. Repeatedly engaging in self-tests thus could be interpreted as an indicator of a higher level of self-reflection. Such an interpretation was underpinned by the observation that some students, in spite of an impressive rehearsal regime, struggled during their first year at university.

The qualitative analyses allowed the careful interpretation that students who participated in study groups were more likely to reflect their learning and to be able to manage the transition to university. It is thus argued that social interaction and peer learning are indeed highly relevant to evoke self-reflection in “at risk” students, even though such a connection could not be made based on the quantitative data. The literature has reported mixed results regarding the effects of peer learning and study groups (Broadbent and Poon, 2015) and there indeed seem many factors involved. First, it is hypothesised that for the acquisition or re-activation of basic skills study groups are less relevant than for developing an understanding for complex mathematical concepts. Second, it could be observed that not all students considered study groups as helpful. Dancer *et al.* (2015) suggested that, to be enabled to benefit from study groups, “at risk” students needed first to learn how to organise and plan the group learning process.

Finally, it was found of particular importance that “at risk” students who studied alone were less likely to accept that they might need help and waited too long before seeking support. Thus help seeking emerged as a highly relevant task strategy in this phase (Karabenick and Knapp, 1991; Newman, 2002; Karabenick, 2004).

Based on the observations made in the qualitative part of the study it is suggested that the effect of poor basic knowledge in mathematics on first year performance in mathematics can be moderated by the following variables (note that only the first three were commensurable with data collected from the e-learning environment):

(1) *Pre-course participation.* Students who participated in the diagnostic pre-test or the pre-course outperformed students who did not. Note that the self-selection bias had to be accounted for; it is suggested that *avoiding* the diagnostic pre-test or the pre-course could be a risk factor in its own right.

(2) *Learning gains in the pre-course*, measured by the difference between pre- and post-test results.

(3) *Self-monitoring and rehearsal*, measured by the number of self-tests a student submitted.

(4) *Self-reflection.* A lack of self-reflection may become visible in a strong performance orientation but is *not* observable by quantitative analyses based on data collected from the e-learning environment.

(5) *Seeking help*. Learners who experience serious problems and not seek help are at risk to fail their course. As high performing students are likely to show similar behaviour (=not seek help) such a risk is not observable by quantitative analyses based on data collected from the e-learning environment. Participating in the e-tutoring course, however, could be identified as one indicator of this self-regulation ability.

## 6.3 Limitations and methodological discussion

As stated at the beginning of this thesis, evaluations of non-mandatory, extra-curricular pre-courses usually lack comprehensive data sets and thus fail to clearly differentiate between covariates and the actual effects of pre-course participation. This study addressed this practical problem by building a reliable and reproducible data model that controlled for prior knowledge and allowed to relate pre-course learning activities with subsequent study success.

A limitation of this study was the open design of the course that did not allow an experimental design. Due to ethical and organisational reasons students were free to self-enrol into the pre-course and the different additional programmes. It can be assumed that students' decisions were influenced by their pre-conditions and educational backgrounds, causing a bias in all analyses. Students with a sound knowledge level in mathematics, for example, are more likely to strive to become even better (Lagerlöf and Seltzer, 2009) whereas students with broad knowledge gaps tend to overestimate their abilities (Bol and Hacker, 2001; Wittwer and Renkl, 2008) and thus may decide against participation. Indeed, if remedial programmes are compulsory for all "at risk" students the literature suggests only weak effects (Ballard and Johnson, 2004; Moss and Yeaton, 2006; Calcagno and Long, 2008; Bettinger and Long, 2009; Di Pietro, 2012). While it was not possible to eliminate this bias all between-group comparisons underwent thorough analyses of student data profiles and were interpreted in the light of these interactions.

The open course design might also have limited the quality of the data collected from the LMS. Learning behaviour in non-mandatory courses can be expected to be less conscientious than at school or university. Furthermore, participants in distance education usually show less commitment and withdraw more often than face-to-face learners (Smith and Ferguson, 2005; Street, 2010; Ashby *et al.*, 2011). In this study, data obtained from tests appeared to be more consistent than data collected from questionnaires. There was a tendency, for example, that more high performing students, more students with a positive attitude, and more students with high learning gains answered the evaluation survey and the learning strategies questionnaire. Such interactions are in alignment with previous research that high performing students find it easier to answer metacognitive items and answer them more consistently (Case, 2004; Thiessen and Blasius, 2008). Concerns thus might be raised regarding the general idea of "measuring" the use of learning strategies with the help of Likert-scaled items (Artelt, 2000).

Tracking learner data on first sight appeared to be a more objective approach to measuring and monitoring student learning. It was found, however, that many learning activities took place outside the university's LMS as students also used external links or studied with printed PDF-files and textbooks (Pardo and Kloos, 2011; Tempelaar *et al.*, 2015).

Finally, it might also be discussed if graduation, cumulated GPA, or examination results are exhaustive measures of study success. For reasons of comparability it seemed appropriate to use these widespread performance measures (Robbins *et al.*, 2004, p. 262; Plant *et al.*, 2005, p. 114) but alternative approaches to measuring "success" in a technical degree programme are certainly conceivable.

## 6.4 Recommendations for practice

This study aimed at making practical suggestions for the design of pre-courses in mathematics, based on repeated evaluations carried out in the pre-study and a concluding analysis carried out in the main study.

*Formative e-assessment*

Formative e-assessment was identified as a vital element of the web-based learning environment that helped learners to structure the learning process. Self-tests and exercises were used by students throughout the course. Learners particularly appreciated item feedback that comprised detailed solutions. Students used problems and test results as scaffolds throughout the learning process, confirming the view that one of the biggest advantages of web-based learning environments is the facilitation and promotion of self-monitoring (Winne, 2004; Nicol and Macfarlane-Dick, 2006). The *diagnostic pre-test* was found particularly helpful for such “feedback loops” (Zimmerman and Moylan, 2009). It raised students’ awareness for the importance of a sound basic knowledge in mathematics and helped them to plan the learning process.

Reflection of test results and making adequate choices based on this reflection, however, seems to be one major challenge for participants in open e-learning environments (Hannafin and Hannafin, 2010). It is suggested that pre-course designs should try to evoke self-reflection by discussing test results with learners and by prompting them more often to evaluate their learning. While there is evidence in the literature that reflection can be learned and that self-regulation instruction will positively affect students’ mathematics performance, research has also shown that students with broad knowledge gaps need more time to benefit from such trainings (Zimmerman *et al.*, 2011; Friedewald *et al.*, 2015). Metacognitive aspects of learning therefore should be included, but a continuation throughout the first year will certainly be necessary.

*Syllabus*

Against expectations, the test analyses did not allow to identify knowledge areas that were more relevant for first year mathematics performance than others. For pre-courses that address students enrolled in different courses and degree programmes it is therefore suggested to provide diagnostic tests and learning materials that cover the complete secondary school syllabus. An abridged syllabus bears the risk that participants underestimate the demands of their course; this study showed that in hindsight students found the pre-course syllabus perfectly adequate.

*Item design*

In this study the provision of items related to the application of mathematics in “daily life”, or in engineering contexts, did not lead to a higher engagement or motivation of students. It is suggested that authenticity and situatedness of learning are more likely to be created by helping learners to interact with each other (Johri and Olds, 2011). However, it is suggested to provide a broad variance of questions, from very basic ones that only demand to apply a certain rule or technique, to application-oriented questions. It is strongly suggested to provide more complex problem solving tasks only in learning environments that are supported by e-tutors.

*Guidance and support*

While a considerable number of students in this study were able to “refresh” their basic knowledge with the help of the web-based learning contents, students with broad knowledge gaps in many cases felt overwhelmed by the task to study independently. For these students additional support was offered in the form of e-tutoring and face-to-face courses. The latter were found disappointingly ineffective; for the group of “at risk” students both their design and duration (one week) were obviously inadequate and left many participants with the (false) impression of being well prepared. It is strongly suggested to design courses that demand a much higher investment of time and effort from this group of learners and provide a clear schedule, periods of self-study and rehearsal, and external monitoring.

*Help seeking*

The e-tutoring course with its higher level of guidance had been designed and recommended particularly for learners with broad knowledge gaps. However, descriptive analyses of the different groups’ prior knowledge level and educational backgrounds suggested that those with the highest risk level more often chose the much shorter face-to-face course. It also was a clear outcome of this study that some first year students were unable to realise that they were “at risk” and waited much too long before seeking help. These results indicated that “at risk” students need to learn how to seek help (Newman, 2002; Robinson and Croft, 2003; Karabenick, 2004). It also emerged that many students lacked knowledge of how to participate in and benefit from group discussions (Ellis *et al.*, 2008).

Thus meta-cognitive and social aspects of learning should be considered more strongly in the didactical design of the pre-course. Information about relations between domain knowledge and the use of learning strategies should be provided in online or face-to-face sessions. Students should be informed of the importance of being able to participate in groups for their chosen career. Edmunds *et al.* (2012), for example, showed that the perceived usefulness for students’ professional lives was a strong argument for using software and technology at university. Similarly, informing engineering students that engagement in group work or web-based communication are relevant working skills might increase their interest in study groups.

*Learning analytics*

One of the practical interests of this study was to explore the informative value of the data collected from the web-based pre-course with regard to the growing field of learning analytics. Studies in this area often focus on the identification of “at risk” students, the prospects being that such data models allow developing early warning systems.

With the diagnostic pre-test that was used in this study such an identification was possible; at the same time, this study showed the limitations of such estimations. The multiple model accounted for 36% of the variance in Mathematics I at most. Compared to similar investigations this was an acceptable to good result. A much more comprehensive model by Ackerman *et al.* (2013), for example, explained 40% of the variance in GPA. At the same time, a lot of variance remained unaccounted for, so that many students succeeded in spite of a poor pre-test result, whereas others who performed reasonably well in the pre-test failed their course (Robinson and

Croft, 2003). Making individual predictions based on such probabilities might provide some students with a false sense of security (Clark and Lovric, 2009), whereas others could try to avoid the "stigmatisation" of being "at risk" (Case, 2004).

Similar considerations should be made regarding the analysis of learner behaviour and the role of tracking data. While it was a significant outcome of this study that the number of self-tests is a better predictor of course performance than many other variables, it did not allow a direct connection between this variable and study success. The interviews conducted with first year students showed how quantitative predictions may fail, as they do not inform on qualitative differences in students' learning routines. "Blind spots" of the learning management system need to be considered, as well: in this study, a relatively large number of students chose to learn offline.

A claim is therefore made to not overemphasise the role of predictive models and to use such data for project evaluation only. The anonymised data collected from this study, for example, were made available for prospective students and could be used for discussions on the relevance of the pre-course participation for study success in technical degree programmes (see www.optes.de).

## 6.5 Recommendations for future research

This study focused on data collected from a standard LMS (Moodle), using questionnaire results and not very sophisticated tracking methods. Some universities are already experimenting with systems that inform students of their “risk status” based on demographic, administrative, and tracking data (Hamburg University of Technology:Knutzen *et al.*, 2014; Stuttgart Media University: Metzger *et al.*, 2015; Dublin City University: Corrigan *et al.*, 2015). It will be interesting to see if more sophisticated learning environments will measure up to the expectations of the learning analytics community (Greller and Drachsler, 2012; Gibson and Ifenthaler, 2017).

It will have to be investigated more deeply how such automated systems can support students in the transition phase, for example by providing adaptive self-assessments. The question banks used in the *optes* project are currently categorised and fed into an adaptive system that will permit generating individually compiled tests for students with differing knowledge levels.

More adaptive learning environments might also allow to address individual learning preferences, for example by providing a variety of representations of a mathematical problem, from abstract to visual to practical application (Kolb and Kolb, 2005; Fleming and Mills, 1992).

The role of social learning analytics, as well, is considered an important field of research in mathematics e-learning. In this study the role of online communication lacked significance, mainly due to a lack of forum activity. Future versions of the pre-course might result in more active online participation which then might generate much more meaningful data.

It should also be investigated how e-portfolios can be implemented in mathematics courses in order to evoke self-reflection in learners (Burks, 2010; McDonald, 2012; O’Sullivan *et al.*, 2017). Some hands-on-experiments have already been conducted in the *optes* project, suggesting that it is quite demanding to meaningfully connect cognitive and metacognitive learning in an engineering context. Certainly more research is needed on how to address not only different levels of domain knowledge but different needs regarding scaffolding and guidance in e-learning environments (Hannafin and Hannafin, 2010).

## 6.6 Conclusion

At the beginning of this thesis the question arose if web-based pre-courses are an adequate answer to the issue of increasing heterogeneity of first year students' mathematics knowledge. This question could not be answered completely positive: while participation in the pre-course significantly affected first year mathematics performance of the "at risk" group it had an even stronger effect on students with a good or very good prior knowledge level. The gap between these groups thus could not be closed by pre-course participation, suggesting that some of the expectations raised by grant programmes such as the Quality Pact for Teaching (BMBF, 2011) might be overoptimistic. Short-term remedial programmes like the pre-course described in this study may help to re-activate school knowledge and thus ease the transition to university, but they are certainly not sufficient instruments when it comes to broad and fundamental gaps in knowledge.

At the same time, this study showed that preparatory courses in mathematics are highly welcomed by students and many participants who were identified to be "at risk" successfully managed the transition to university. By focusing on this group's learning activities this study answered the question what variables can be related to an improved first year performance and what are covariates of prior performance. By differentiating between these factors this study helped to clarify the role of learning environment for learners with poor domain knowledge and self-regulation skills.

It also showed the limitations of quantitative analysis when it comes to make suggestions for individual students. It was demonstrated that the group of "at risk" students is highly heterogeneous, as well, and that predictive models are only useful for general course evaluations but not to make accurate predictions of an individual learner's academic career. Such an interpretation was underpinned by the observation that some students, in spite of an impressive rehearsal regime in the pre-course, struggled during their first year at university. It is suggested that quantitative pre-course evaluations have "blind spots" as they fail to inform if students' learning activities remained on the surface or resulted in deeper understanding or self-reflection.

The answer to the overarching research question

> How does participation in a web-based pre-course in mathematics impact first year tertiary performance of "at risk" students?

thus was multifaceted. It was shown that a structured and guided environment as provided by the e-tutoring course, setting schedules and prompting students to keep them, positively affected the number of learning activities as well as learning outcomes. As students with the highest risk level were found to less often choose this course, the role of self-monitoring and reflection about test results could be identified as one highly relevant self-regulatory skill.

It is concluded that the very small period of time available to help students with knowledge gaps in mathematics should be used to raise their awareness about the mathematics problem and to engage them in self-assessment and self-monitoring activities. As this study demonstrated it is challenging to find the right balance between activating learners and reinforcing performance orientations. More should therefore be done to evoke self-reflection about test results, to enable students to communicate about their problems with mathematics, and to enable learners to benefit from studying in groups.

# 7 References


Abel, H. and Weber, B. (2014), "28 Jahre Esslinger Modell - Studienanfänger und Mathematik", in Bausch, I., Biehler, R., Bruder, R., Fischer, P.R., Hochmuth, R., Koepf, W., Schreiber, S. and Wassong, T. (Eds.), *Mathematische Vor- und Brückenkurse*, Springer, Wiesbaden, pp. 9-19.

Ackerman, P.L., Kanfer, R. and Beier, M.E. (2013), "Trait Complex, Cognitive Ability, and Domain Knowledge Predictors of Baccalaureate Success, STEM Persistence and Gender Differences", *Journal of Educational Psychology*, Vol. 105 No. 3, pp. 911-927.

Aiken, L.R. (1974), "Two scales of attitude toward mathematics", *Journal for Research in Mathematics Education No.* 5, pp. 67-71.

Al-Holou, N., Bilgutay, N.M., Corleto, C., Demel, J.T., Felder, R.M., Frair, K., Froyd, J.E., Hoit, M., Morgan, J. and Wells, D.L. (1999), "First-Year Integrated Curricula: Design Alternatives and Examples", *Journal of Engineering Education*, Vol. 88 No. 4, pp. 435-448.

Amelink, C.T. (2012), "Female Interest in Mathematics", in Bogue, B. and Cady, E. (Eds.), *Apply Research to Practice (ARP) Resources*.

Anderson, L.W. and Krathwohl, D.R. (2001), *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives,* Abridged ed., Longman, New York.

Anderson, T. and Shattuck, J. (2012), "Design-Based Research", *Educational Researcher*, Vol. 41 No. 1, pp. 16-25.

Armstrong, P.K. and Croft, A.C. (1999), "Identifying the Learning Needs in Mathematics of Entrants to Undergraduate Engineering Programmes in an English University", *European Journal of Engineering Education*, Vol. 24 No. 1, pp. 59-71.

Artelt, C. (2000), *Strategisches Lernen*, Waxmann, Münster.

Artelt, C., Baumert, J., Julius-McElvany, N. and Peschar, J. (2003), *Learners for life: Student approaches to learning. Results from PISA 2000*.

Artino, A.R. and Stephens, J.M. (2009), "Academic motivation and self-regulation: A comparative analysis of undergraduate and graduate students learning online", *Internet and Higher Education,* Vol. 12, pp. 146-151.

Ashby, J., Sadera, W.A. and Mcnary, S.W. (2011), "Comparing student success between developmental math courses offered online, blended, and face-to-face", *Journal of Interactive Online Learning*, Vol. 10 No. 3, pp. 128-140.

Autorengruppe Bildungsberichterstattung (2012), *Bildung in Deutschland 2012. Ein indikatorengestützter Bericht mit einer Analyse zur kulturellen Bildung im Lebenslauf,* Bielefeld.

Azevedo, R. (2005), "Using Hypermedia as a Metacognitive Tool for Enhancing Student Learning? The Role of Self-Regulated Learning", *Educational Psychologist*, Vol. 40 No. 4, pp. 199-209.

Azevedo, R. and Cromley, J.G. (2004), "Does Training on Self-Regulated Learning Facilitate Students' Learning With Hypermedia?", *Journal of Educational Psychology*, Vol. 96 No. 3, pp. 523-535.

Azevedo, R., Cromley, J.G. and Seibert, D. (2004a), "Does adaptive scaffolding facilitate students' ability to regulate their learning with hypermedia?", *Contemporary Educational Psychology*, Vol. 29 No. 3, pp. 344-370.

Azevedo, R., Guthrie, J.T. and Seibert, D. (2004b), “The Role of Self-Regulated Learning in Fostering Students' Conceptual Understanding of Complex Systems with Hypermedia”, *Journal of Educational Computing Research*, Vol. 30 1-2, pp. 87-111.

Azevedo, R., Moos, D.C., Greene, J.A., Winters, F.I. and Cromley, J.C. (2008), “Why is externally regulated learning more effective than self-regulated learning with hypermedia?”, *Educational Technology Research and Development*, Vol. 56 No. 1, pp. 45-72.

Azevedo, R., Moos, D.C., Johnson, A.M. and Chauncey, A.D. (2010), “Measuring Cognitive and Metacognitive Regulatory Processes During Hypermedia Learning: Issues and Challenges”, *Educational Psychologist*, Vol. 45 No. 4, pp. 210-223.

Baeten, M., Kyndt, E., Struyven, K. and Dochy, F. (2010), “Using student-centred learning environments to stimulate deep approaches to learning: Factors encouraging or discouraging their effectiveness”, *Educational Research Review*, Vol. 5 No. 3, pp. 243-260.

Ballard, C.L. and Johnson, M. (2004), “Basic Math Skills and Performance in an Introductory Economics Class”, *Journal of Economic Education*, Vol. 35 No. 1, pp. 3-23.

Bandura, A. (1977a), “Self-efficacy: Toward a unifying theory of behavioral change”, *Psychological Review*, Vol. 84 No. 2, pp. 191-215.

Bandura, A. (1977b), *Social learning theory*, Prentice Hall, Englewood Cliffs, NJ.

Bargel, T. (2015), *Studieneingangsphase und heterogene Studentenschaft - neue Angebote und ihr Nutzen: Befunde des 12. Studierendensurveys an Universitäten und Fachhochschulen, Hefte zur Bildungs- und Hochschulforschung 83*.

Barnard, L., Lan, W.Y., To, Y.M., Osland Paton, V. and Lai, S.-L. (2009), “Measuring self-regulation in online and blended learning environments”, *Internet and Higher Education*, Vol. 12, pp. 1-6.

Barnard-Brak, L., Lan, W.Y. and Paton, V.O. (2010), “Profiles in Self-Regulated Learning in the Online Learning Environment”, *International Review of Research in Open and Distance Learning*, Vol. 11 No. 1, pp. 62-80.

Baumert, J., Klieme, E., Neubrand, M., Prenzel, M., Schiefele, U., Schneider, W., Tillmann, K.-J. and Weiß, M. (2000), “Fähigkeit zum selbstregulierten Lernen als fächerübergreifende Kompetenz”, available at: http://www.mpib-berlin.mpg.de/Pisa/CCCdt.pdf (accessed 22 November 2013).

Bausch, I., Fischer, P.R. and Oesterhaus, J. (2014), “Facetten von Blended Learning Szenarien für das interaktive Lernmaterial VEMINT - Design und Evaluationsergebnisse an den Partneruniversitäten Kassel, Darmstadt und Paderborn”, in Bausch, I., Biehler, R., Bruder, R., Fischer, P.R., Hochmuth, R., Koepf, W., Schreiber, S. and Wassong, T. (Eds.), *Mathematische Vor- und Brückenkurse*, Springer, Wiesbaden, pp. 87-102.

Bennett, R.E., Braswell, J., Oranje, A., Sandene, B., Kaplan, B. and Yan, F. (2008a), “Does it Matter if I Take My Mathematics Test on Computer? A Second Empirical Study of Mode Effects in NAEP”, *Journal of Technology, Learning, and Assessment*, Vol. 6 No. 9.

Bennett, S., Maton, K. and Kervin, L. (2008b), “The ‘digital natives’ debate: A critical review of the evidence”, *British Journal of Educational Technology*, Vol. 39 No. 5, pp. 775-786.

Berkaliev, Z. and Kloosterman, P. (2009), “Undergraduate engineering majors’ beliefs about mathematics”, *School Science and Mathematics*, Vol. 109, pp. 175-182.

Bernard, R.M., Abrami, P.C., Lou, Y., Borokhovski, E., Wade, A. and Wozney, L. (2004), “How Does Distance Education Compare With Classroom Instruction? A Meta-Analysis of the Empirical Literature”, *Review of Educational Research*, Vol. 74 No. 3, pp. 379-439.

Bernold, L.E., Bingham, W.L., McDonald, P.H. and Attia, T.M. (2000), “Impact of Holistic and Learning-Oriented Teaching on Academic Success”, *Journal of Engineering Education*, Vol. 89 No. 2, pp. 191-200.

Bescherer, C. (2003), “Selbsteinschätzung der mathematischen Studierfähigkeit von Studienanfängerinnen und -anfängern”, Dissertation, Pädagogische Hochschule Ludwigsburg, Ludwigsburg, 2003.

Besterfield-Sacre, M., Atman, C.J. and Shuman, L.J. (1996), “Changes in freshman engineers’ attitudes. A cross institutional comparison what makes a difference?”, in *Frontiers in Education Conference Proceedings*, pp. 78-82.

Besterfield-Sacre, M., Atman, C.J. and Shuman, L.J. (1997), “Characteristics of Freshman Engineering Students: Models for Determining Student Attrition in Engineering”, *Journal of Engineering Education*, Vol. 86 No. 2, pp. 139-149.

Besterfield-Sacre, M., Atman, C.J. and Shuman, L.J. (1998), “Engineering Student Attitudes Assessment”, *Journal of Engineering Education*, Vol. 87 No. 2, pp. 133-141.

Besterfield-Sacre, M., Cox, M.F., Borrego, M., Beddoes, K. and Zhu, J. (2014), “Changing Engineering Education: Views of U.S. Faculty, Chairs, and Deans”, *Journal of Engineering Education*, Vol. 103 No. 2, pp. 193-219.

Bettinger, E.P. and Long, B.T. (2009), “Addressing the Needs of Underprepared Students in Higher Education: Does College Remediation Work?”, *Journal of Human Resources*, Vol. 44 No. 3, pp. 736-771.

Biehler, R., Fischer, P.R. and Wassong, T. (2012), “Designing and evaluating blended learning bridging courses in mathematics”, in *Congress of the European Society for Research in Mathematics Education, Rzeszow, Poland*, pp. 1971-1980.

Biggs, J.B. (1976), “Dimensions of study behaviour: Another look at ATI”, *British Journal of Educational Psychology*, Vol. 46 No. 1, pp. 68-80.

Biggs, J.B. (1978), “Individual and group differences in study processes”, *British Journal of Educational Psychology*, Vol. 48, pp. 266-279.

Biggs, J.B. (1987a), *Learning Process Questionnaire (LPQ) Manual*, Hawthorn.

Biggs, J.B. (1987b), *Study Process Questionnaire (SPQ) Manual. Student Approaches to Learning and Studying*, Hawthorn.

Biggs, J.B. and Moore, P.J. (1993), *The Process of Learning*, Prentice Hall, New York.

Black, P., Harrison, C., Lee, C., Marshall, B. and Wiliam, D. (2003), *Assessment for Learning: Putting it into practice*, Open University Press.

Black, P. and Wiliam, D. (1998), “Assessment and classroom learning”, *Assessment in Education*, Vol. 5 No. 1, pp. 7-71.

Black, P. and Wiliam, D. (2009), “Developing the theory of formative assessment”, *Educational Assessment, Evaluation and Accountability* 21(1).

Bloom, B.S. (1956), *Taxonomy of educational objectives. The classification of educational goals: Handbook 1, Cognitive domain*, Vol. 1, Longman, London.

Blum, W., Vogel, S., Drüke-Noe, C. and Roppelt, A. (Eds.) (2015), *Bildungsstandards aktuell: Mathematik in der Sekundarstufe II*, Schroedel, Braunschweig.

BMBF Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research) (2011), “Quality pact for teaching”, project data base, available at: https://www.bmbf.de/de/qualitaetspakt-lehre-524.html (accessed 22 November 2017).

Boekaerts, M., Pintrich, P.R. and Zeidner, M. (Eds.) (2000), *Handbook of self-regulation*, Academic Press, New York, NY.
Boerner, S., Seeber, G., Keller, H. and Beinborn, P. (2005), "Lernstrategien und Lernerfolg im Studium: Zur Validierung des LIST bei berufstätigen Studierenden", *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie*, Vol. 37 No. 1, pp. 17-25.
Bol, L. and Hacker, D.J. (2001), "A Comparison of the Effects of Practice Tests and Traditional Review on Performance and Calibration", *The Journal of Experimental Education*, Vol. 69 No. 2, pp. 133-151.
Bollnow, O.F. (1978), *Vom Geist des Übens: Eine Rückbesinnung auf elementare didaktische Erfahrung*, Herder, Freiburg i. Br.
Bönsch, M. (2014), *Nachhaltiges Lernen durch Üben und Wiederholen*, Schneider Verlag Hohengehren, Baltmannsweiler.
Booth, S. (2008), "Learning and teaching engineering mathematics for the knowledge society", *European Journal of Engineering Education*, Vol. 33 No. 3, pp. 381-389.
Bosse, E. and Trautwein, C. (2014), "Individuelle und institutionelle Herausforderungen der Studieneingangsphase", *Zeitschrift für Hochschulentwicklung*, Vol. 9 No. 5, pp. 41-62.
Bowyer, K. (2012), "A model of student workload", *Journal of Higher Education Policy and Management*, Vol. 34 No. 3, pp. 239-258.
Brennan, R.L. (Ed.) (2006), *Educational Measurement*, Praeger, Westport.
Brinkmann, M. (2011), "Üben", in Kade, J., Helsper, W., Lüders, C., Egloff, B., Radtke, F.-O. and Thole, W. (Eds.), *Pädagogisches Wissen, Erziehungswissenschaften in Grundbegriffen*, Kohlhammer, Stuttgart, pp. 140-146.
Brint, S., Cantwell, A.M. and Hanneman, R.A. (2008), "The Two Cultures of Undergraduate Academic Engagement", *Research in Higher education*, Vol. 49 No. 5, pp. 383-402.
Britton, B.K. and Tesser, A. (1991), "Effects of time-management practices on college grades", *Journal of Educational Psychology*, Vol. 83 No. 3, pp. 405-410.
Broadbent, J. (2017), "Comparing online and blended learner's self-regulated learning strategies and academic performance", *The Internet and Higher Education*, Vol. 33, pp. 24-32.
Broadbent, J. and Poon, W.L. (2015), "Self-regulated learning strategies & academic achievement in online higher education learning environments: A systematic review", *The Internet and Higher Education*, Vol. 27, pp. 1-13.
Bromley, D.B. (1986), *The case-study method in psychology and related disciplines*, Wiley, Chichester.
Brown, A.L., Collins, A. and Duguid, P. (1989), "Situated cognition and the culture of learning", *Educational Researcher No.* 18, pp. 32-42.
Bruner, J.S. (1978), "Learning how to do things with words", in Bruner, J.S. and Garton, A. (Eds.), *Human Growth and Development*, Clarendon, Oxford, pp. 62-84.
Budny, D., LeBold, W. and Bjedow, G. (1998), "Assessment of the Impact of Freshman Engineering Courses", *Journal of Engineering Education*, Vol. 87 No. 4, pp. 405-411.
Bühner, M. (2006), *Einführung in die Test- und Fragebogenkonstruktion*, Pearson, München.
Burks, R. (2010), "The Student Mathematics Portfolio: Value Added to Student Preparation?", *PRIMUS*, Vol. 20 No. 5, pp. 453-472.

Calcagno, J.C. and Long, B.T. (2008), “The Impact of Postsecondary Remediation Using a Regression Discontinuity Approach. Addressing Endogenous Sorting and Noncompliance”, *NBER Working Paper No.* 14194.

Campbell, J.P. and Oblinger, D.G. (2007), “Academic Analytics”, *EDUCAUSE Learning Initiative*.

Caracelli, V.J. and Greene, J.C. (1997), “Crafting Mixed-Method Evaluation Designs”, *New Directions for Evaluation*, Vol. 74 No. 2, pp. 19-32.

Carell, A. (2006), *Selbststeuerung und Partizipation beim computergestützten kollaborativen Lernen*, Waxmann, Münster.

Carr, M., Bowe, B. and Ní Fhloinn, E. (2013), “Core skills assessment to improve mathematical competency”, *European Journal of Engineering Education*, Vol. 38 No. 6, pp. 608-619.

Carraher, D.W. and Schliemann, A.D. (2008), “Revisiting mathematics in and out of school”, in *SIPEMAT International symposium on Mathematics Education Research, Recife, Pernambuco*.

Carson, A.D. (2011), “Predicting Student Success from the Lassi for Learning Online (LLO)”, *Journal of Educational Computing Research*, Vol. 45 No. 4, pp. 399-414.

Case, J.M. (2000), “Students' perceptions of context, approaches to learning and metacognitive development in a second year chemical engineering course”, Monash University, Melbourne, 2000.

Case, J.M. (2004), “Approaches to Learning: A Critical Examination of Inventory Responses from Third Year Chemical Engineering Students”, in Buffler, A. and Laugksch, R.C. (Eds.), *Proceedings of the 12th annual conference of the Southern African Association for Research in Mathematics, Science and Technology Education SAARMSTE, Cape Town, 13-17 January*, pp. 102-110.

Case, J.M. and Light, G. (2011), “Emerging Methodologies in Engineering Education Research”, *Journal of Engineering Education*, Vol. 100 No. 1, pp. 186-210.

Case, J.M. and Marshall, D. (2004), “Between deep and surface: procedural approaches to learning in engineering education contexts”, *Studies in Higher Education*, Vol. 29 No. 5, pp. 605-615.

Casey, D.M. (2008), “A Journey to Legitimacy: The Historical Development of Distance Education through Technology”, *TechTrends*, Vol. 52 No. 2, pp. 45-51.

CEDEFOP (2001), *E-learning and training in Europe. A survey into the use of e-learning in training and professional development in the European Union: Cedefop Reference series*, Luxembourg.

Chamberlin, S.A. (2010), “A review of Instruments Created to Assess Affect in Mathematics”, *Journal of Mathematics Education*, Vol. 3 No. 1, pp. 167-182.

Chang, M.-M. (2007), “Enhancing web-based language learning through self-monitoring”, *Journal of Computer Assisted Learning*, Vol. 23 No. 3, pp. 187-196.

ChanLin, L.-J. (2012), “Learning strategies in web-supported collaborative project”, *Innovations in Education and Teaching International*, Vol. 49 No. 3, pp. 319-331.

Clarebout, G., Elen, J., Lowyck, J., van den Ende, J. and Van den Enden, E. (2004), “Evaluation of an open learning environment: The contribution of evaluation to the ADDIE process”, in Armstrong, A. (Ed.), *Structional design in the real world*, Idea Group, Hershey, PA, pp. 119-135.

Clark, M. and Lovric, M. (2008), "Suggestion for a theoretical model for secondary-tertiary transition in mathematics", *Mathematics Education Research Journal*, Vol. 22 No. 2, pp. 25-37.
Clark, M. and Lovric, M. (2009), "Understanding secondary-tertiary transition in mathematics", *International Journal of Mathematical Education in Science and Technology*, Vol. 40 No. 6, pp. 755-776.
Clark, R.E. and Craig, T.G. (1992), "Research and Theory on Multi-Media Learning Effects", in Giardina, M. (Ed.), *Interactive Multimedia Learning Environments: Human Factors,Technical Considerations on Design Issues*, Springer, Berlin, Heidelberg, pp. 19-30.
Clark, R.E. and Feldon, D.F. (2005), "Five Common but Questionable Principles of Multimedia Learning", in Mayer, R.E. (Ed.), *The Cambridge handbook of multimedia learning*, Cambridge University Press, New York, pp. 97-116.
Clark, R.E. and Salomon, G. (1986), "Media in teaching", in Wittrock, M.C. (Ed.), *Handbook of research on teaching*, 3rd ed., Macmillan, New York.
Cobb, P., Confrey, J., diSessa, A., Lehrer, R. and Schauble, L. (2003), "Design experiments in educational research", *Educational Researcher*, Vol. 32 No. 1, pp. 9-13.
Coe, R.J. (2017), "The nature of educational research", in Coe, R.J., Waring, M., Hedges, L.V. and Arthur, J. (Eds.), *Research Methods and Methodologies in Education*, Sage, Los Angeles, pp. 5-14.
Coffield, F., Moseley, D., Hall, E. and Ecclestone, K. (2004), *Learning styles and pedagogy in post-16 learning: A systematic and critical review*, London.
Cohen, J. (1988), *Statistical power analysis for the behavioral sciences*, Lawrence Erlbaum, Hillsdale, NJ.
Cole, R., Purao, S., Rossi, M. and Sein, M.K. (2005), "Being proactive: Where action research meets design research", in *Proceedings of the 26th International Conference on Information Systems*.
Collins, A., Joseph, D. and Bielaczyc, K. (2004), "Design Research: Theoretical and Methodological Issues", *Journal of the Learning Sciences*, Vol. 13 No. 1, pp. 15-42.
Collins, K.M.T. (2012), "Is mixed research science? Empirical evidence from the field of educational research (Epilogue)", *International Journal of Multiple Research Approaches*, Vol. 6 No. 3, pp. 332-342.
Cook, C., Heath, F. and Thompson, R.L. (2000), "A meta-analysis of response rates in web- or internet-based surveys", *Educational and psychological measurement*, Vol. 60 No. 6, pp. 821-836.
Corrigan, O., Glynn, M., KcKenna, A., Smeaton, A. and Smyth, S. (2015), "Student Data: Data is Knowledge. Putting the Knowledge Back in the Students' Hands", in *14th European Conference on e-Learning ECEL, Hatfield, UK, 29-30 Oct*, pp. 165-172.
cosh cooperation schule:hochschule (2014), *Mindestanforderungskatalog Mathematik (2.0) der Hochschulen Baden-Württembergs für ein Studium von WiMINT-Fächern*.
Crawford, K., Gordon, S., Nicholas, J. and Prosser, M. (1994), "Conceptions of mathematics and how it is learned: The perspectives of students entering university", *Learning and Instruction*, Vol. 4 No. 4, pp. 331-345.
Crawford, K., Gordon, S., Nicholas, J. and Prosser, M. (1998a), "Qualitatively different experiences of learning mathematics at university", *Learning and Instruction*, Vol. 8 No. 5, pp. 455-468.

Crawford, K., Gordon, S., Nicholas, J. and Prosser, M. (1998b), "University mathematics students conceptions of mathematics", *Studies in Higher Education*, Vol. 23 No. 1, pp. 87-94.

Credé, M. and Phillips, L.A. (2011), "A meta-analytic review of the Motivated Strategies for Learning Questionnaire", *Learning and Individual Differences*, Vol. 21 No. 4, pp. 337-346.

Creswell, J.W. (2013), *Qualitative inquiry and research design: Choosing among five approaches,* 3rd ed., Sage, Los Angeles.

Creswell, J.W. and Plano Clark, V.L. (2011), *Designing and conducting mixed methods research*, Sage, Los Angeles, CA.

Cretchley, P. (2008), "Advancing Research Into Affective Factors in Mathematics Learning: Clarifying Key Factors, Terminology and Measurement", in Goos, M., Brown, R. and Makar, K. (Eds.), *Proceedings of the 31st Annual Conference of the Mathematics Education Research Group of Australasia*, pp. 147-153.

Croft, A.C., Harrison, M.C. and Robinson, C.L. (2009), "Recruitment and retention of students - an integrated and holistic vision of mathematics support", *International Journal of Mathematical Education in Science and Technology*, Vol. 40 No. 1, pp. 109-125.

Crotty, M. (1998), *The foundations of social research: meaning and perspective in the research process,* Sage, London.

Crowther, K., Thompson, D. and Cullingford, C. (1997), "Engineering degree students are deficient in mathematical expertise - why?", *International Journal of Mathematical Education in Science and Technology*, Vol. 28 No. 6, pp. 785-792.

Cuban, L. (1986), *The Classroom Use of Technology Since 1920*, Teachers College Press, New York.

Dancer, D., Morrison, K. and Tarr, G. (2015), "Measuring the effects of peer learning on students' academic achievement in first-year business statistics", *Studies in Higher Education*, Vol. 40 No. 10, pp. 1808-1828.

Davison, R.M., Martinsons, M.G. and Kock, N. (2004), "Principles of Canonical Action Research", *Information Systems Journal*, Vol. 14 No. 1, pp. 65-86.

DeCorte, E. and Masui, C. (2009), "Enhancing the learning proficiency of students in higher education", available at: http://forumonpublicpolicy.com/summer08papers/archivesummer08/decorte.pdf (accessed 10 November 2014).

DeCorte, E., Verschaffel, L. and Op't Eynde, P. (2000), "Self-regulation: A characteristic and a goal of mathematics education", in Boekaerts, M., Pintrich, P.R. and Zeidner, M. (Eds.), *Handbook of self-regulation*, Academic Press, New York, NY, pp. 687-726.

Dehling, H., Glasmachers, E., Griese, B., Härterich, J. and Kallweit, M. (2014), "MP2 - Mathe/Plus/Praxis: Strategien zur Vorbeugung gegen Studienabbruch", *Zeitschrift für Hochschulentwicklung*, Vol. 9 No. 4, pp. 39-56.

Denzin, N.K. (1994), "The Art and Politics of Interpretation", in Denzin, N.K. and Lincoln, Y.S. (Eds.), *Handbook of Qualitative Research*, Sage, Thousand Oaks, pp. 500-515.

Design-Based Research Collective (2003), "Design-Based Research: An Emerging Paradigm for Educational Inquiry", *Educational Researcher*, Vol. 32 No. 1, pp. 5-8.

DHBW Präsidium (2012), *Jahresbericht der Dualen Hochschule Baden-Württemberg 2011/2012*, Stuttgart.

Di Pietro, G. (2012), *The short-term effectiveness of a remedial mathematics course: evidence from a UK university, Discussion Paper Series*, Bonn.
Dieter, M. (2011), "Studienabbruch und Studienfachwechsel in der Mathematik: Quantitative Bezifferung und empirische Untersuchung von Bedingungsfaktoren", Fakultät für Mathematik, Universität Duisburg-Essen, 2011.
Downes, S. (2012), "Connectivism and Connective Knowledge. Essays on meaning and learning networks", available at: http://www.downes.ca/files/books/Connective_Knowledge-19May2012.pdf (accessed 24 November 2016).
Dreier, O. (2014), "Entwicklung eines Moodle Plug-Ins zur erweiterten Auswertung von Tests. Bachelor Thesis", Duale Hochschule Baden-Württemberg, Mannheim, 2014.
Dürrschnabel, K., Klein, H.-D., Niederdrenk-Felgner, C., Dürr, R., Weber, B. and Wurth, R. (2013), *Mindestanforderungskatalog Mathematik der Hochschulen Baden-Württembergs für ein Studium von MINT oder Wirtschaftsfächern (WiMINT)*, report, conference date July 5 2012, Esslingen.
Dweck, C.S. (1986), "Motivational Processes Affecting Learning", *American Psychologist*, Vol. 41 No. 10, pp. 1040-1048.
Ecclestone, K., Biesta, G. and Hughes, M. (Eds.) (2010), *Transitions and Learning through the Lifecourse*, Routledge, London.
Edmunds, R., Thorpe, M. and Conole, G. (2012), "Student attitudes towards and use of ICT in course study, work and social activity: A technology acceptance model approach", *British Journal of Educational Technology*, Vol. 43 No. 1, pp. 71-84.
Ehrenberg, R.G. (2010), "Analyzing the factors that influence persistence rates in STEM field, majors: Introduction to the symposium", *Economics of Education Review*, Vol. 29, pp. 888-891.
Eley, M.G. and Meyer, J.H.F. (2004), "Modelling the influences on learning outcomes of study processes in university mathematics", *Higher Education*, Vol. 47 No. 4, pp. 437-454.
Elias, T. (2011), "Learning Analytics: Definitions, Processes and Potential", *Learning and Knowledge*.
Ellis, R.A., Goodyear, P., Calvo, R.A. and Prosser, M. (2008), "Engineering students' conceptions of and approaches to learning through discussions in face-to-face and online contexts", *Learning and Instruction*, Vol. 18 No. 3, pp. 267-282.
Engineering Council (2000), *Measuring the Mathematics Problem*, London.
Entwistle, N.J., Hanley, M. and Hounsell, D. (1979), "Identifying distinctive approaches to studying", *Higher Education*, Vol. 8 No. 4, pp. 365-380.
Entwistle, N.J. and McCune, V. (2004), "The Conceptual Bases of Study Strategy Inventories", *Educational Psychology Review*, Vol. 16 No. 4, pp. 325-345.
Entwistle, N.J. and Ramsden, P. (1983), *Understanding student learning*, Croom Helm, London.
Entwistle, N.J. and Tait, H. (1990), "Approaches to learning, evaluations of teaching, and preferences for contrasting academic environments", *Higher Education*, Vol. 19 No. 2, pp. 169-194.
Ericsson, K.A., Krampe, R.T. and Tesch-Romer, C. (1993), "The Role of Deliberate Practice in the Acquisition of Expert Performance", *Psychological Review*, Vol. 100 No. 3, pp. 363-406.
ESG (2015), *Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG)*, Brussels.

Fan, W. and Yan, Z. (2010), “Factors affecting response rates of the web survey: A systematic review”, *Computers in Human Behavior*, Vol. 26, pp. 132-139.
Faulkner, F., Hannigan, A. and Fitzmaurice, O. (2014), “The role of prior mathematical experience in predicting mathematics performance in higher education”, *International Journal of Mathematical Education in Science and Technology*, Vol. 45 No. 5, pp. 648-667.
Faulkner, F., Hannigan, A. and Gill, O. (2010), “Trends in the mathematical competency of university entrants in Ireland by leaving certificate mathematics grade”, *Teaching Mathematics and its Applications*, Vol. 29 No. 2, pp. 76-93.
Felder, R.M. and Brent, R. (2005), “Understanding student differences”, *Journal of Engineering Education*, pp. 57-72.
Felder, R.M. and Silverman, L.K. (1988), “Learning and Teaching Styles”, *Journal of Engineering Education*, Vol. 78 No. 7, pp. 674-681.
Fennema, E. and Sherman, J.A. (1976), “Fennema-Sherman Mathematics Attitudes Scales: Instruments Designed to Measure Attitudes toward the Learning of Mathematics by Females and Males”, *Journal for Research in Mathematics Education*, Vol. 7 No. 5, pp. 324-326.
Ferrare, J.J. and Hora, M.T. (2014), “Cultural Models of Teaching and Learning in Math and Science: Exploring the Intersections of Culture, Cognition, and Pedagogical Situations”, *The Journal of Higher Education*, Vol. 85 No. 6, pp. 792-825.
Fischer, F., Mandl, H. and Todorova, A. (2009), “Lehren und Lernen mit neuen Medien”, in Tippelt, R. and Schmidt, B. (Eds.), *Handbuch Bildungsforschung*, 2nd ed., VS Verlag, pp. 753-771.
Fischer, P.R. (2014), *Mathematische Vorkurse im Blended Learning Format. Konstruktion, Implementation und wissenschaftliche Evaluation.*, Springer Spektrum, Wiesbaden.
Flavell, J.H. (1979), “Metacognition and cognitive monitoring. A new area of cognitive-developmental inquiry”, *American Psychologist*, Vol. 34 No. 10, pp. 906-911.
Fleming, N.D. and Mills, C. (1992), “Not Another Inventory, Rather a Catalyst for Reflection”, *To Improve the Academy*, Vol. 11 No. 137.
Flyvbjerg, B. (2006), “Five Misunderstandings About Case-Study Research”, *Qualitative Inquiry*, Vol. 12 No. 2, pp. 219-245.
Fogarty, G.G., Cretchley, P., Harman, C., Ellerton, N. and Konki, N. (2001), “Validation of a questionnaire to measure mathematics confidence, computer confidence, and attitudes towards the use of technology for learning mathematics”, *Mathematics Education Research Journal*, Vol. 13, pp. 154-160.
Francis, R. and Shannon, S.J. (2013), “Engaging with blended learning to improve students’ learning outcomes”, *European Journal of Engineering Education*, Vol. 38 No. 4, pp. 359-369.
Frey, A., Asseburg, R., Ehmke, T. and Blum, W. (2008), “Mathematische Kompetenz im Ländervergleich”, in Prenzel, M., Artelt, C., Baumert, J., Blum, W., Hammann, M., Klieme, E. and Pekrun, R. (Eds.), *PISA 2006 in Deutschland. Die Kompetenzen der Jugendlichen im dritten Ländervergleich*, Waxmann, Münster, pp. 127-148.
Friedewald, D., Nicolaisen, T. and Schnieder, J. (2015), “Lernstrategien im Rahmen mathematischer Tutorien und tutorieller Fach-Coachings”, in Martin, P.-Y. and Nicolaisen, T. (Eds.), *Lernstrategien fördern: Modelle und Praxisszenarien*, Beltz Juventa, Weinheim, Basel, pp. 258-281.

Froyd, J.E. and Ohland, M.W. (2005), “Integrated Engineering Curricula”, *Journal of Engineering Education*, Vol. 94 No. 1, pp. 147-164.
Gainsburg, J. (2015), “Engineering Students' Epistemological Views on Mathematical Methods in Engineering”, *Journal of Engineering Education*, Vol. 104 No. 2, pp. 139-166.
Galbraith, P. and Haines, C. (1998), “Disentangling the nexus: Attitudes to mathematics and technology in a computer learning environment”, *Educational Studies in Mathematics*, Vol. 36, pp. 275-290.
Gasiewski, J., Eagan, M., Garcia, G., Hurtado, S. and Chang, M. (2012), “From Gatekeeping to Engagement: A Multicontextual, Mixed Method Study of Student Academic Engagement in Introductory STEM Courses”, *Research in Higher education*, Vol. 53 No. 2, pp. 229-261.
Gebel, T., Grenzer, M., Kreusch, J., Liebig, S., Schuster, H., Tscherwinka, R., Watteler, O. and Witzel, A. (2015), “Verboten ist, was nicht ausdrücklich erlaubt ist: Datenschutz in qualitativen Interviews”, *Forum: Qualitative Sozialforschung*, Vol. 16 No. 2, p. 27-27.
Genlott, A.A. and Grönlund, Å. (2016), “Closing the gaps - Improving literacy and mathematics by ict-enhanced collaboration”, *Computers & Education*, Vol. 99, pp. 68-80.
Gerring, J. (2009), *Case Study Research: Principles and practices*, Cambridge University Press, Cambridge.
Gherardi, S. and Turner, B. (1987), *Real men don't collect soft data, Quaderno 13*, Università di Trento, Trento.
Gibbs, G. and Simpson, C. (2004), “Conditions under which assessment supports student learning”, *Learning and Teaching in Higher Education*, Vol. 1 No. 1, pp. 3-31.
Gibson, D.C. and Ifenthaler, D. (2017), “Preparing the Next Generation of Education Researchers for Big Data in Higher Education”, in Daniel, B.K. (Ed.), *Big data and learning analytics in higher education: Current theory and practice*, Springer, Basel, pp. 29-42.
Gill, O. and O'Donoghue, J. (2008), “A Theoretical Characterisation of Service Mathematics”, in *ICME 11, Monterrey*, TSG24.
Gleason, J. (2008), “An Evaluation of Mathematics Competitions Using Item Response Theory”, *Notices of the American Mathematical Society*, Vol. 55 No. 1, pp. 8-15.
Goldstein, P. and Katz, R.N. (2005), “Academic Analytics: The Uses of Management Information and Technology in Higher Education”.
Gorard, S. (2007), “Mixing methods is wrong: An everyday approach to educational justice”, in British Educational Research Association (Ed.), *British Educational Research Association Annual Conference, London, 5-8 September*.
Granić, A. and Ćukušić, M. (2011), “Usability Testing and Expert Inspections Complemented by Educational Evaluation. A Case Study of an e-Learning Platform”, *Educational Technology & Society*, Vol. 14 No. 2, pp. 107-123.
Greefrath, G., Koepf, W. and Neugebauer, C. (2016), “Is there a link between Preparatory Course Attendance and Academic Success? A Case Study of Degree Programmes in Electrical Engineering and Computer Science”, *International Journal of Research in Undergraduate Mathematics Education*, Vol. 3 No. 1, pp. 143-167.
Greefrath, G., Neugebauer, C., Koepf, W. and Hoever, G. (2014), “Studieneingangstests und Studienerfolg. Mögliche Zusammenhänge am Beispiel zweier Hochschulen”, in Roth, J. and Ames, J. (Eds.), *Beiträge zum Mathematikunterricht*, WTM, Münster, pp. 451-454.

Greene, J.A. and Azevedo, R. (2007), “A Theoretical Review of Winne and Hadwin's Model of Self-Regulated Learning: New Perspectives and Directions”, *Review of Educational Research*, Vol. 77, pp. 334-372.
Greene, J.A., Costa, L.-J., Robertson, J., Pan, Y. and Deekens, V.M. (2010), “Exploring relations among college students’ prior knowledge, implicit theories of intelligence, and self-regulated learning in a hypermedia environment”, *Computers & Education*, Vol. 55, pp. 1027-1043.
Greene, J.C. (1994), “Qualitative Program Evaluation”, in Denzin, N.K. and Lincoln, Y.S. (Eds.), *Handbook of Qualitative Research*, Sage, Thousand Oaks, pp. 530-544.
Greene, J.C., Benjamin, L. and Goodyear, L. (2001), “The Merits of Mixing Methods in Evaluation”, *Evaluation*, Vol. 7 No. 1, pp. 25-44.
Greller, W. and Drachsler, H. (2012), “Translating Learning into Numbers: A Generic Framework for Learning Analytics”, *Educational Technology & Society*, Vol. 15 No. 3, pp. 42-57.
Grotlüschen, A. (2003), “Widerständiges Lernen im Web - virtuell selbstbestimmt? Eine qualitative Studie über E-Learning in der beruflichen Erwachsenenbildung”, Dissertation, Univ., FB Erziehungswiss, Münster, Hamburg, 2003.
Guba, E.G. and Lincoln, Y.S. (1989), *Fourth Generation Evaluation*, Sage, Newbury Park.
Guba, E.G. and Lincoln, Y.S. (1994), “Competing Paradigms in Qualitative Research”, in Denzin, N.K. and Lincoln, Y.S. (Eds.), *Handbook of Qualitative Research*, Sage, Thousand Oaks, pp. 105-117.
Guloy, S., Salimi, F., Cukierman, D. and McGee Thompson, D. (2017), “Insights on supporting learning during computing science and engineering students’ transition to university: a design-oriented, mixed methods exploration of instructor and student perspectives”, *Higher Education*, Vol. 73 No. 3, pp. 479-497.
Gynnild, V. and Myrhaug, D. (2012), “Revisiting approaches to learning in science and engineering: a case study”, *European Journal of Engineering Education*, Vol. 37 No. 5, pp. 458-470.
Haché, A. (2011), “Under the Radar: The Contribution of Civil Society and Third Sector Organisations to eInclusion”, in European Commission (Ed.), *JRT Joint Research Centre Scientific and Technical Reports*.
Hacker, D.J. (Ed.) (2009), *Handbook of Metacognition in Education*, Routledge, New York.
Halford, E. and Lea, J. (2014), “From teaching to learning: how quality assurance in UK higher education has responded to this shift by promoting a culture of enhancement”, in EQAF (Ed.), *Changing education - QA and the shift from teaching to learning, University of Barcelona, 13-15 November*.
Hambleton, R.K. and Swaminathan, H. (2010), *Item response theory. Principles and applications*, Kluwer Academic Publishers, Boston, Dordrecht, Lancaster.
Hammersley, M. (2012), “Methodological Paradigms in Educational Research. British Educational Research Association on-line resource”, available at: https://www.bera.ac.uk/wp-content/uploads/2014/03/Methodological-Paradigms.pdf (accessed 12 April 2015).
Hannafin, M.J. and Hannafin, K.M. (2010), “Cognition and Student-Centered,Web-Based Learning: Issues and Implications for Research and Theory”, in Spector, J.M., Ifenthaler, D., Isaias, P., Kinshuk and Sampson, D. (Eds.), *Learning and Instruction in the Digital Age*, Springer, pp. 11-23.

Harris, D., Black, L., Hernandez-Martinez, P., Pepin, B., Williams, J. and with the TransMaths Team (2015), “Mathematics and its value for engineering students: what are the implications for teaching?”, *International Journal of Mathematical Education in Science and Technology*, Vol. 46 No. 3, pp. 321-336.
Härterich, J., Kiss, C., Rooch, A., Mönnigmann, M., Schulze Darup, M. and Span, R. (2012), “MathePraxis - connecting firstyear mathematics with engineering applications”, *European Journal of Engineering Education*, Vol. 37 No. 3, pp. 255-266.
Harvey, L., Drew, S. and Smith, M. (2006), *The first-year experience: a review of literature for the Higher Education Academy*, York.
Hattie, J. (2009), *Visible learning. A synthesis of over 800 meta-analyses relating to achievement*, Routledge, London.
Hattie, J., Biggs, J.B. and Purdie, N. (1996), “Effects of Learning Skills Interventions on Student Learning. A Meta-Analysis”, *Review of Educational Research*, Vol. 66 No. 2, pp. 99-136.
HEFCE (2013), *Non-continuation rates at English HEIs. Trends for entrants 2005-06 to 2010-11*.
Heidenreich, S. (2009), *Pädagogische Anforderungen an das Lernhandeln im E-Learning: Dimensionen von Selbstlernkompetenz, Medienpädagogik und Mediendidaktik*, Dr. Kovac, Hamburg.
Helmke, A. and Schrader, F.-W. (2000), “Procrastination im Studium - Erscheinungsformen und motivationale Bedingungen”, in Wild, K.P. and Schiefele, U. (Eds.), *Interesse und Lernmotivation. Untersuchungen zu Entwicklung, Förderung und Wirkung*, Waxmann, München, pp. 207-225.
Henn, G. and Polaczek, C. (2007), “Studienerfolg in den Ingenieurwissenschaften”, *Das Hochschulwesen*, Vol. 55 No. 5, pp. 144-147.
Heritage, M. (2007), “Formative Assessment: What do teachers need to know and do?”, *Phi Delta Kappan*, Vol. 89 No. 2, pp. 140-145.
Herzig, B. (2007), “Selbstreguliertes Lernen - eine konzeptionelle Einordnung und Reflexion”, in Ministerium für Schule und Weiterbildung NRW (Ed.), *Wege zu selbstreguliertem Lernen: Beispiele aus dem mathematisch-naturwissenschaftlichen Unterricht*, Ernst Klett, Stuttgart, pp. 208-239.
Heublein, U., Hutzsch, C., Schreiber, J., Sommer, D. and Besuch, G. (2009), *Ursachen des Studienabbruchs in Bachelor- und in herkömmlichen Studiengängen: Ergebnisse einer bundesweiten Befragung von Exmatrikulierten des Studienjahres 2007/08*, Projektbericht.
Heublein, U., Richter, J., Schmelzer, R. and Sommer, D. (2012), *Die Entwicklung der Schwund- und Studienabbruchquoten an den deutschen Hochschulen: Statistische Berechnungen auf der Basis des Absolventenjahrgangs 2010*, Projektbericht.
Hockings, C., Cooke, S. and Bowl, M. (2010), “Learning and teaching in two universities within the context of increasing student diversity - complexity, contradictions and challenges”, in David, M.E. (Ed.), *Improving Learning by Widening Participation in Higher Education*, Routledge, Milton Park, New York, pp. 95-108.
Hoffmeister, K. (2005), “Von der Überflüssigkeit eines Begriffs. Bildung mit E-Learning”, in *Die Google-Gesellschaft. Vom digitalen Wandel des Wissens*, Transcript, Bielefeld, pp. 283-288.
Honey, P. and Mumford, A. (1992), *The manual of learning styles*, 3rd ed., P. Honey, Maidenhead.

Hopf, C. (2004), “Qualitative Interviews: An Overview”, in Flick, U., Kardorff, E. von and Steinke, I. (Eds.), *A Companion to Qualitative Research*, Sage, London, pp. 203-208.

Howson, A.G., Barnard, A.D., Crighton, D.G., Davies, N., Gardiner, A.D., Jagger, J.M., Morris, D., Robson, J.C. and Steele, N.C. (1995), “Tackling the mathematics problem”, Joint report by London Mathematical Society, Institute of Mathematics and its Applications, Royal Statistical Society, available at: http://www.mei.org.uk/files/pdf/Tackling_the_Mathematics_Problem.pdf (accessed 8 January 2017).

Hrastinski, S., Keller, C. and Carlsson, S.A. (2010), “Design exemplars for synchronous e-learning: A design theory approach”, *Computers & Education*, Vol. 55 No. 2, pp. 652-662.

Hutchings, M., Quinney, A., Galvin, K. and Clark, V. (2013), “The Yin/Yang of Innovative Technology Enhanced Assessment for Promoting Student Learning”, in Greener, S. (Ed.), *Case Studies in e-Learning Research for Researchers, Teachers and Students*, Academic Publishing International, Reading, pp. 62-79.

Jackson, D.C. and Johnson, E.D. (2013), “A hybrid model of mathematics support for science students emphasizing basic skills and discipline relevance”, *International Journal of Mathematical Education in Science and Technology*, Vol. 44 No. 6, pp. 846-864.

Jacobs, B. (2008), “Was wissen wir über die Lernwirksamkeit von Aufgabenstellungen und Feedback”, in Thonhauser, J. (Ed.), *Aufgaben als Katalysatoren von Lernprozessen. Eine zentrale Komponente organisierten Lehrens und Lernens aus der Sicht von Lernforschung, allgemeiner Didaktik und Fachdidaktik*, Waxmann, Münster/München/Berlin, pp. 99-114.

Jahnke, I. (2010), “Dynamics of social roles in a knowledge management community”, *Computers in Human Behavior*, Vol. 26 No. 4, pp. 533-546.

JISC Joint Information Systems Comittee (2008), *JISC Study of Shared Services in UK Further and Higher Education. Report 2: The software currently in use for administrative systems in UK FE and HE.*

Johnson, M. and Kuennen, E. (2006), “Basic Math Skills and Performance in an Introductory Statistics Course”, *Journal of Statistics Education*, Vol. 14 No. 2.

Johnson, P. and O’Keeffe, L. (2016), “The effect of a pre-university mathematics bridging course on adult learners’ self-efficacy and retention rates in STEM subjects”, *Irish Educational Studies*, Vol. 35 No. 3, pp. 233-248.

Johnson, R.B. and Onwuegbuzie, A.J. (2004), “Mixed Methods Research: A Research Paradigm Whose Time Has Come”, *Educational Researcher*, Vol. 33 No. 7, pp. 14-26.

Johri, A. and Olds, B.M. (2011), “Situated Engineering Learning: Bridging Engineering Education Research and the Learning Sciences”, *Journal of Engineering Education*, Vol. 100 No. 1, pp. 151-185.

Jones, B.D., Chittum, J.R., Akalin, S., Schram, A.B., Fink, J., Schnittka, C., Evans, M.A. and Brandt, C. (2015), “Elements of Design-Based Science Activities That Affect Students’ Motivation”, *School Science and Mathematics*, Vol. 115 No. 8, pp. 404-415.

Jurecka, A. (2008), “Introduction to the computer-based assessment of competencies”, in Hartig, J., Klieme, E. and Leutner, D. (Eds.), *Assessment of competencies in educational contexts*, Hogrefe, Göttingen, pp. 193-213.

Kablan, Z. (2016), “The effect of manipulatives on mathematics achievement across different learning styles”, *Educational Psychology*, Vol. 36 No. 2, pp. 277-296.

Kadijevich, D. (2006), “Developing Trustworthy Timss Background Measures: A Case Study On Mathematics Attitude”, *The Teaching of Mathematics No.* 2, pp. 41-51.
Kahnwald, N. (2013), *Informelles Lernen in virtuellen Gemeinschaften. Nutzungspraktiken zwischen Information und Partizipation, Medien in der Wissenschaft*, Vol. 62, Waxmann, Münster.
Kaiser, K. (2009), “Protecting Respondent Confidentiality in Qualitative Research”, *Qualitative Health Research*, Vol. 19 No. 11, pp. 1632-1641.
Kaleidoscope seed project (2007), *Self-regulated Learning in Technology Enhanced Learning Environments: A European Review*.
Kalyuga, S., Ayres, P., Chandler, P. and Sweller, J. (2003), “The Expertise Reversal Effect”, *Educational Psychologist*, Vol. 38 No. 1, pp. 23-31.
Kane, M.T. (2013), “Validating the Interpretations and Uses of Test Scores”, *Journal of Educational Measurement*, Vol. 50 No. 1, pp. 1-73.
Karabenick, S.A. (2004), “Perceived Achievement Goal Structure and College Student Help Seeking”, *Journal of Educational Psychology*, Vol. 96 No. 3, pp. 569-581.
Karabenick, S.A. and Knapp, J.R. (1988), “Help seeking and the need for academic assistance”, *Journal of Educational Psychology*, Vol. 80 No. 3, pp. 406-408.
Karabenick, S.A. and Knapp, J.R. (1991), “Relationship of academic help seeking to the use of learning strategies and other instrumental achievement behavior in college students”, *Journal of Educational Psychology*, Vol. 83 No. 2, pp. 221-230.
Karjalainen, A.A.K.J.S. (2006), *Give me time to think. Determining student workload in higher education*, Oulu.
Kehm, B.M. (2010), “Quality in European Higher Education: The Influence of the Bologna Process”, *Change: The Magazine of Higher Learning*, Vol. 42 No. 3, pp. 40-46.
Kelly, A. (2009), “In defence of anonymity. Rejoining the criticism”, *British Educational Research Journal*, Vol. 35 No. 3, pp. 431-445.
Kember, D. (2004), “Interpreting student workload and the factors which shape students' perceptions of their workload”, *Studies in Higher Education*, Vol. 29 No. 2, pp. 165-184.
Kember, D., Ng, S., Tse, H., Wong, E.T.T. and Pomfret, M. (1996), “An examination of the interrelationships between workload, study time, learning approaches and academic outcomes”, *Studies in Higher Education*, Vol. 21 No. 3, pp. 347-358.
Kempen, L. (2016), “Das soziale Netzwerk Facebook als unterstützende Maßnahme für Studierende im Übergang Schule/Hochschule”, in Hoppenbrock, A., Biehler, R., Hochmuth, R. and Rück, H.-G. (Eds.), *Lehren und Lernen von Mathematik in der Studieneingangsphase: Herausforderungen und Lösungsansätze*, Springer Spektrum, Berlin, pp. 311-320.
Kendall Brown, M., Hershock, C., Finelli, C.J. and O’Neal, C. (2009), *Teaching for Retention in Science, Engineering, and Math Disciplines: A Guide for Faculty, CRLT Occasional Paper*, Ann Arbor, MI.
Kent, P. (2002), “Should we reassess the role of Mathematics in Engineering education? Maths CAA Series”, available at: http://ltsn.mathstore.ac.uk/articles/maths-caa-series/dec2002/index.shtml (accessed 12 December 2016).
Kerres, M. (2004), “Warum Notebook-Universität? Von der virtuellen Hochschule zum mobilen Lernen auf dem digitalen Campus”, in Kerres, M. (Ed.), *Didaktik der Notebook-Universität, Medien in der Wissenschaft*, Waxmann, Münster, pp. 7-27.

Kerres, M. (2006), “Potenziale von Web 2.0 nutzen”, in Hohenstein, A. and Wilbers, K. (Eds.), *Handbuch E-Learning*, DWD, München.
Kerres, M., Ojstersek, N., Preussler, A. and Stratmann, J. (2009), “E-Learning-Umgebungen in der Hochschule: Lehrplattformen und persönliche Lernumgebungen”, in Dittler, U., Krameritsch, J., Nistor, N., Schwarz, C. and Thillosen, A. (Eds.), *E-Learning: Eine Zwischenbilanz: Kritischer Rückblick als Basis eines Aufbruchs*, Waxmann, Münster, pp. 101-116.
Kerres, M. and Witt, C. de (2004), “Pragmatismus als theoretische Grundlage für die Konzeption von eLearning”, in Treichel, D. and Meyer, H.O. (Eds.), *Handlungsorientiertes Lernen und eLearning. Grundlagen und Praxisbeispiele*, Oldenbourg, München, pp. 22-100.
Kift, S., Nelson, K. and Clarke, J. (2010), “Transition pedagogy: A third generation approach to FYE - A case study of policy and practice for the higher education sector”, *The International Journal of the First Year in Higher Education*, Vol. 1 No. 1, pp. 1-20.
Kinnebrew, J.S., Segedy, J.R. and Biswas, G. (2014), “Analyzing the temporal evolution of students’ behaviors in open-ended learning environments”, *Metacognition and Learning*, Vol. 9 No. 2, pp. 187-215.
Kirkwood, A. and Price, L. (2005), “Learners and learning in the twenty-first century: what do we know about students’ attitudes towards experiences of information and communication technologies that will help us design courses?”, *Studies in Higher Education*, Vol. 33 No. 3, pp. 257-274.
Kloosterman, P. and Stage, F. (1992), “Measuring beliefs about mathematical problem solving”, *School Science and Mathematics*, Vol. 92, pp. 109-115.
Kluger, A.N. and DeNisi, A. (1996), “Effects of feedback intervention on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory”, *Psychological Bulletin*, Vol. 119 No. 2, pp. 254-284.
Knospe, H. (2008), “Der Mathematik-Eingangstest an Fachhochschulen in Nordrhein-Westfalen. Proceedings des 6. Workshops Mathematik für Ingenieure”, *Wismarer Frege-Reihe No.* 3, pp. 6-11.
Knospe, H. (2011), “Der Eingangstest Mathematik an Fachhochschulen in Nordrhein-Westfalen von 2002 bis 2010. Proceedings des 9. Workshops Mathematik für ingenieurwissenschaftliche Studiengänge”, *Wismarer Frege-Reihe No.* 2, pp. 8-13.
Knowles, M.S. (1975), *Self-directed learning: A guide for learners and teachers*, Prentice Hall, Englewood Cliffs, NJ.
Knutzen, S., Kallies, H., Daldrop, L., Klaffke, H. and Ladwig, T. (2014), “Individuelles Lernen in der gestreckten Studieneingangsphase mytrack”, in Morschheuser, P. (Ed.), *Qualifizierung von Studierenden im Student-Life-Cycle*, pp. 51-55.
Koedinger, K.R. and Corbett, A. (2006), “Cognitive Tutors: Technology Bringing Learning Science to the Classroom”, in Sawyer, R.K. (Ed.), *The Cambridge Handbook of the Learning Sciences*, Cambridge University Press, New York, pp. 61-78.
Kokkelenberg, E. and Sinha, E. (2010), “Who succeeds in STEM studies? An analysis of Binghamton University undergraduate students”, *Economics of Education Review*, Vol. 29, pp. 935-946.
Kolari, S., Savander-Ranne, C. and Viskari, E.-L. (2006), “Do our engineering students spend enough time studying?”, *European Journal of Engineering Education*, Vol. 31, pp. 499-508.

Kolari, S., Savander-Ranne, C. and Viskari, E.-L. (2008), “Learning needs time and effort: a time-use study of engineering students”, *European Journal of Engineering Education*, Vol. 33 5-6, pp. 483-498.

Kolb, A.Y. and Kolb, D.A. (2005), “Learning styles and learning spaces. Enhancing experiential learning in higher education”, *Academy of Management Learning & Education*, Vol. 4, pp. 193-212.

Kolb, A.Y. and Kolb, D.A. (2009), “The Learning Way. Meta-cognitive Aspects of Experiential Learning”, *Simulation & Gaming*, Vol. 40 No. 3, pp. 297-327.

Kolb, D.A. (1984), *Experiential Learning. Experience as the Source of Learning and Development*, Prentice Hall, Englewood Cliffs, NJ.

Köller, O., Baumert, J. and Bos, W. (2002), “TIMSS Third International Mathematics and Science Study”, Dritte internationale Mathematik- und Naturwissenschaftsstsudie, in Weinert, F.E. (Ed.), *Leistungsmessungen in Schulen, Beltz Pädagogik*, 2., unveränd. Aufl., Dr. nach Typoskript., Beltz, Weinheim, pp. 269-284.

Koppel, O. (2013), *2012: Ingenieure auf einen Blick. Erwerbstätigkeit, Innovation, Wertschöpfung: Report*.

Koro-Ljungberg, M. and Douglas, E.P. (2008), “State of Qualitative Research in Engineering Education: Meta-Analysis of JEE Articles, 2005-2006”, *Journal of Engineering Education*, Vol. 97 No. 2, pp. 163-175.

Kramarski, B. and Gutman, M. (2006), “How can self-regulated learning be supported in mathematical E-learning environments?”, *Journal of Computer Assisted Learning*, Vol. 22 No. 1, pp. 24-33.

Kramer, J., Nagy, G., Trautwein, U., Lüdtke, O., Jonkmann, K., Maaz, K. and Treptow, R. (2011), “Die Klasse an die Universität, die Masse an die anderen Hochschulen? Wie sich Studierende unterschiedlicher Hochschultypen unterscheiden”, *Zeitschrift für Erziehungswissenschaft*, Vol. 14, pp. 465-487.

Krapp, A. and Prenzel, M. (2011), “Research on Interest in Science: Theories, methods, and findings”, *International Journal of Science Education*, Vol. 33 No. 1, pp. 27-50.

Krause, K.-L., Hartley, R., James, R. and McInnis, C. (2005), *The first year experience in Australian universities. Findings from a decade of national studies: Final Report*, Melbourne.

Kreidl, C. (2011), *Akzeptanz und Nutzung von E-Learning-Elementen an Hochschulen. Gründe für die Einführung und Kriterien der Anwendung von E-Learning, Medien in der Wissenschaft*, Vol. 59, Waxmann, Münster.

Krockover, G.H., Shepardson, D.P., Adams, P.E., Eichinger, D. and Nakhleh, M. (2002), “Reforming and Assessing Undergraduate Science Instruction Using Collaborative Action-Based Research Teams”, *School Science and Mathematics*, Vol. 102 No. 6, pp. 266-284.

Krumke, S.O., Roegner, K., Schüler, L., Seiler, R. and Stens, R. (2012), “Der Online-Mathematik Brückenkurs OMB. Eine Chance zur Lösung der Probleme an der Schnittstelle Schule/Hochschule. DMV Mitteilungen Juni 2012”, available at: http://page.math.tu-berlin.de/~seiler/publications/OMB-eine-Chance.pdf (accessed 21 January 2017).

Kuncel, N.R. and Hezlett, S.A. (2007), “Standardized Tests Predict Graduate Students’ Success”, *Science Education*, Vol. 315 No. 5815, pp. 1080-1081.

Lagerlöf, J.N.M. and Seltzer, A.J. (2009), “The effects of remedial mathematics on the learning of economics: evidence from a natural experiment”, *The Journal of Economic Education*, Vol. 40 No. 2, pp. 115-137.

Lather, P. (2006), “Paradigm proliferation as a good thing to think with. Teaching research in education as a wild profusion”, *International Journal of Qualitative Studies in Education*, Vol. 19 No. 1, pp. 35-57.
Laurillard, D. (1979), “The processes of student learning”, *Higher Education*, Vol. 8 No. 4, pp. 395-409.
Laurillard, D. (2005), “Styles and Approaches in Problem-solving”, in Marton, F., Hounsell, D. and Entwistle, N.J. (Eds.), *The Experience of Learning: Implications for teaching and studying in higher education*, 3rd ed., Centre for Teaching, Learning and Assessment, University of Edinburgh, pp. 126-144.
Lave, J. (1988), *Cognition in Practice: Mind, mathematics and culture in everyday life*, Cambridge University Press, New York.
Lave, J. and Wenger, E. (1991), *Situated learning: legitimate peripheral participation*, Cambridge University Press, New York.
Lawson, D. (2000), “Changes in the Competency of A Level Students”, in The Engineering Council (Ed.), *Measuring the Mathematics Problem*, London, pp. 6-9.
Lawson, D. (2003), *Diagnostic testing for mathematics: LTSN MathsTEAM Project*.
Ledermüller, K. and Fallmann, I. (2017), “Predicting learning success in online learning environments: Self-regulated learning, prior knowledge and repetition”, *Zeitschrift für Hochschulentwicklung*, Vol. 12 No. 1, pp. 79-99.
Levin, M. and Greenwood, D.J. (2008), “The Future of Universities: Action Research and the Transformation of Higher Education”, in Reason, P. and Bradbury, H. (Eds.), *The Sage handbook of action research. Participative inquiry and practice*, Sage, Los Angeles, CA, pp. 211-226.
Li, L. (2015), “Project-based learning in electronic technology: a case study”, *European Journal of Engineering Education*, Vol. 40 No. 5, pp. 499-505.
Linacre, J.M. (2002), “What do Infit and Outfit, Mean-square and Standardized mean?”, *Rasch Measurement Transactions*, Vol. 16 No. 2, p. 878-878.
Liston, M. and O'Donoghue, J. (2007), “The Transition from Secondary School Mathematics to University Mathematics”, in *5.-8.9*.
Litzinger, T., Lattuca, L.R., Hadgraft, R. and Newstetter, W. (2011), “Engineering Education and the Development of Expertise”, *Journal of Engineering Education*, Vol. 100 No. 1, pp. 123-150.
Lumsdaine, M. and Lumsdaine, E. (1995), “Thinking Preferences of Engineering Students: Implications for Curriculum Restructuring”, *Journal of Engineering Education*, Vol. 84 No. 2, pp. 193-204.
Macan, T.H., Shahani, C., Dipboye, R.L. and Phillips, A.P. (1990), “College Students' Time Management: Correlations With Academic Performance and Stress”, *Journal of Educational Psychology*, Vol. 82 No. 4, pp. 760-768.
Macfadyen, L.P. and Dawson, S. (2010), “Mining LMS data to develop an ‘early warning system' for educators: A proof of concept”, *Computers & Education*, Vol. 54 No. 2, pp. 588-599.
Mair, P. and Hatzinger, R. (2007), “CML based estimation of extended Rasch models with the eRm package in R”, *Psychology Science*, Vol. 49 No. 1, pp. 26-43.
Malmivuori, M.-L. (2001), “The dynamics of affect, cognition, and social environment in the regulation of personal learning processes. The case of mathematics”, Dissertation, Faculty of Education, University of Helsinki, 2001.
Marbouti, F., Diefes-Dux, H.A. and Madhavan, K. (2016), “Models for early prediction of at-risk students in a course using standards-based grading”, *Computers & Education*, Vol. 103, pp. 1-15.

Marbouti, F., Diefes-Dux, H.A. and Strobel, J. (2015), “Building course-specific regression-based models to identify at-risk students”, in *The American Society for Engineering Educators Annual Conference, Seattle*, ID 11229.
March, S.T. and Smith, G.F. (1995), “Design and Natural Science Research on Information Technology”, *Decision Support Systems*, Vol. 15 No. 4, pp. 251-266.
March, S.T. and Storey, V.C. (2008), “Design Science in the Information Systems Discipline. An Introduction to the Special Issue on Design Science Research”, *MIS Quarterly*, Vol. 32 No. 4, pp. 725-730.
Marsden, E. and Torgerson, C.J. (2012), “Single group, pre- and post-test research designs: Some methodological concerns”, *Oxford Review of Education*, Vol. 38 No. 5, pp. 583-616.
Marshall, D. (1995), “The relationship between learning conceptions, approaches to learning and learning outcomes in foundation year engineering students”, D.Phil. thesis, University of Oxford, Oxford, 1995.
Martin, M.O., Mullis, I.V.S., Foy, P. and Arora, A. (2012), “Creating and Interpreting the TIMSS and PIRLS 2011 Context Questionnaire Scales”, in Martin, M.O. and Mullis, I.V.S. (Eds.), *Methods and Procedures in TIMSS and PIRLS 2011*, Boston College, Chestnut Hill.
Martin, P.-Y. (2012), “Lernstrategien und Umgang mit ICT von Studienanfängerinnen und -anfängern”, Institut für Psychologie, Universität Zürich, 2012.
Marton, F., Dall'Alba, G. and Beaty, E. (1993), “Conceptions of learning”, *International Journal of Educational Research*, Vol. 19 No. 3, pp. 277-300.
Marton, F., Dall'Alba, G. and Tse, L.K. (1996), “Memorizing and understanding: the keys to the paradox?”, in Watkins, D. and Biggs, J.B. (Eds.), *The Chinese learner: cultural, psychological, and contextual influences*, Comparative Education Research Centre, Hong Kong, pp. 69-83.
Marton, F., Hounsell, D. and Entwistle, N.J. (Eds.) (2005a), *The Experience of Learning: Implications for teaching and studying in higher education*, 3rd ed., Centre for Teaching, Learning and Assessment, University of Edinburgh.
Marton, F. and Säljö, R. (1976), “On qualitative differences in learning. I Outcome and process”, *British Journal of Educational Psychology*, Vol. 46, pp. 4-11.
Marton, F. and Säljö, R. (2005), “Approaches to learning”, in Marton, F., Hounsell, D. and Entwistle, N.J. (Eds.), *The Experience of Learning: Implications for teaching and studying in higher education*, 3rd ed., Centre for Teaching, Learning and Assessment, University of Edinburgh, pp. 39-58.
Marton, F., Wen, Q. and Wong, K.C. (2005b), “Read a hundred times and the meaning will appear …? Changes in Chinese University Students views of the temporal structure of learning”, *Higher Education*, Vol. 49 No. 3, pp. 291-318.
MAXQDA, *MAXQDA: software for qualitative data analysis*, VERBI Software Consult Sozialforschung GmbH, Berlin.
Mayer, R.E. (2003), “The promise of multimedia learning: using the same instructional design methods across different media”, *Learning and Instruction*, Vol. 13, pp. 125-139.
Mayer, R.E. (2005), “Introduction to Multimedia Learning”, in Mayer, R.E. (Ed.), *The Cambridge handbook of multimedia learning*, Cambridge University Press, New York, pp. 1-16.
Mayring, P. (2000), “Qualitative Inhaltsanalyse”, in Flick, U., Kardorff, E. von and Steinke, I. (Eds.), *Qualitative Forschung. Ein Handbuch*, *Rowohlts Enzyklopädie*, Rowohlt Taschenbuch Verlag, Reinbek, pp. 468-474.

Mayring, P. (2014), *Qualitative content analysis. Theoretical foundation, basic procedures and software solution*, Klagenfurt.
Mazur, E. (1997), *Peer Instruction: A User's Manual, Series in Educational Innovation*, Prentice Hall, Upper Saddle River, NJ.
McCarthy, J.C. and Wright, P.C. (2004), *Technology as experience*, MIT Press, Cambridge, MA.
McDonald, B. (2012), "Portfolio assessment: direct from the classroom", *Assessment & Evaluation in Higher Education*, Vol. 37 No. 3, pp. 335-347.
McDowell, L. (1995), "Effective Teaching and Learning on Foundation and Access Courses in Engineering, Science and Technology", *European Journal of Engineering Education*, Vol. 20 No. 4, pp. 417-425.
McEachron, D.L., Bach, C. and Sualp, M. (2012), "Digital Socrates: a system for disseminating and evaluating best practices in education", *Campus-Wide Information Systems*, Vol. 29 No. 4, pp. 226-237.
McManus, T.F. (2000), "Individualizing instruction in a web-based hypermedia learning environment: nonlinearity, advance organizers, and self-regulated learners", *Journal of Interactive Learning Research*, Vol. 11 No. 3, pp. 219-251.
McNaught, C., Lam, P. and Cheng, K.F. (2012), "Investigating relationships between features of learning designs and student learning outcomes", *Educational Technology Research and Development*, Vol. 60 No. 2, pp. 271-286.
Meiner, S. and Seiler, R. (2009), "Abschlussbericht Expertentreffen Brückenkurs Mathematik", in BMBF (Ed.), *Expertentreffen Brückenkurs Mathematik, Gustav Stresemann Institut, Bonn*.
Merton, R.K. (1987), "The focussed interview and focus groups. Continuities and discontinuities", *Public Opinion Quarterly*, Vol. 51, pp. 550-566.
Metzger, C., Hinkelmann, M., Lüssem, J., Maucher, J., Rieck, A. and Seidl, T. (2015), "Softwaregestützte Analyse von Studienverläufen - neue Grundlagen für Studienberatung, Qualitäts- und Lehrentwicklung", in Nistor, N. and Schirlitz, S. (Eds.), *Digitale Medien und Interdisziplinarität, Medien in der Wissenschaft*, Waxmann, Münster, pp. 303-305.
Mevarech, Z.R. and Fridkin, S. (2006), "The effects of IMPROVE on mathematical knowledge, mathematical reasoning and meta-cognition", *Metacognition and Learning*, Vol. 1 No. 1, pp. 85-97.
Meyer, J.H.F. (2000), "Variation in contrasting forms of 'memorising' and associated observables", *British Journal of Educational Psychology*, Vol. 70 No. 2, pp. 163-176.
Meyer, J.H.F. and Eley, M.G. (1999), "The development of affective subscales to reflect variation in students' experiences of studying mathematics in higher education", *Higher Education*, Vol. 37, pp. 197-216.
Michael, W.B., Michael, J.J. and Zimmerman, W.S. (1988), *Study Attitudes and Methods Survey*, Edits, San Diego, California.
Michinov, N., Brunot, S., Le Bohec, O., Juhel, J. and Delaval, M. (2011), "Procrastination, participation, and performance in online learning environments", *Computers & Education*, Vol. 56 No. 1, pp. 243-252.
Middendorf, E., Apolinarski, B.P.J., Kandulla, M. and Netz, N. (2013), *Die wirtschaftliche und soziale Lage der Studierenden in Deutschland 2012: 20. Sozialerhebung*, Berlin, Bonn.
Molenaar, I. and Järvelä, S. (2014), "Sequential and temporal characteristics of self and socially regulated learning", *Metacognition and Learning*, Vol. 9 No. 2, pp. 75-85.

Moos, D.C. and Azevedo, R. (2008), “Self-regulated learning with hypermedia: the role of prior domain knowledge”, *Contemporary Educational Psychology*, Vol. 33 No. 2, pp. 270-298.
Morgan, D.L. (1988), *Focus groups as qualitative research*, Sage, Newbury Park.
Morgan, D.L. (2007), “Paradigms Lost and Pragmatism Regained”, *Journal of Mixed Methods Research*, Vol. 1 No. 1, pp. 48-76.
Morris, L.V., Finnegan, C. and Wu, S.-S. (2005), “Tracking student behavior, persistence, and achievement in online courses”, *The Internet and Higher Education*, Vol. 8 No. 3, pp. 221-231.
Moss, B.G. and Yeaton, W.H. (2006), “Shaping Policies Related to Developmental Education: An Evaluation Using the Regression-Discontinuity Design”, *Educational Evaluation and Policy Analysis*, Vol. 28 No. 3, pp. 215-229.
MPFS (2013), *JIM-STUDIE 2013. Jugend, Information, (Multi-) Media: Basisstudie zum Medienumgang 12- bis 19-Jähriger in Deutschland*, Medienpädagogischer Forschungsverbund Südwest.
Mullis, I.V.S., Martin, M.O., Foy, P. and Arora, A. (2012), *TIMSS 2011 International Results in Mathematics*.
Mullis, I.V.S., Martin, M.O., Ruddock, G.J., O'Sullivan, C.Y. and Preuschoff, C. (2009), *TIMSS 2011 Assessment Frameworks*.
Mustoe, L. (2002), “Mathematics in engineering education”, *European Journal of Engineering Education*, Vol. 27 No. 3, pp. 237-240.
Narciss, S., Proske, A. and Koerndle, H. (2007), “Promoting self-regulated learning in web-based learning environments”, *Computers in Human Behavior*, Vol. 23, pp. 1126-1144.
Newman, R.S. (2002), “How Self-Regulated Learners Cope with Academic Difficulty: The Role of Adaptive Help Seeking”, *Theory into practice*, Vol. 41 No. 2, pp. 132-138.
Nicol, D.J. and Macfarlane-Dick, D. (2006), “Formative assessment and self-regulated learning: A model and seven principles of good feedback practice”, *Studies in Higher Education*, Vol. 31 No. 2, pp. 199-218.
Nielsen, J. (2010), “College Students on the Web”, available at: http://www.nngroup.com/articles/college-students-on-the-web (accessed 15 December 2015).
O’Sullivan, C., Robinson, P., Keogh, J. and O’Neill, J. (2017), “Models of re-engaging adult learners with mathematics”, *Teaching Mathematics and its Applications*, Vol. 36 No. 2, pp. 81-93.
Offer, J. and Bos, B. (2009), “The design and application of technology-based courses in the mathematics classroom”, *Computers & Education*, Vol. 53 No. 4, pp. 1113-1137.
Olds, B.M., Borrego, M., Besterfield-Sacre, M. and Cox, M. (2012), “Continuing the Dialog: Possibilities for Community Action Research in Engineering Education”, *Journal of Engineering Education*, Vol. 101 No. 3, pp. 407-411.
Olds, B.M. and Miller, R.L. (2004), “The Effect of a First-Year Integrated Engineering Curriculum on Graduation Rates and Student Satisfaction: A Longitudinal Study”, *Journal of Engineering Education*, Vol. 93 No. 1, pp. 23-35.
Orhun, N. (2013), “The effects of learning styles on high school students’ achievement on a mathematics course”, *Educational Research and Reviews*, Vol. 8 No. 14, pp. 1158-1165.
Osborne, J., Simon, S. and Collins, S. (2003), “Attitudes towards science: A review of the literature and its implications”, *International Journal of Science Education*, Vol. 25 No. 9, pp. 1049-1079.

Pachman, M., Sweller, J. and Kalyuga, S. (2013), “Levels of knowledge and deliberate practice”, *Journal of Experimental Psychology: Applied*, Vol. 19 No. 2, pp. 108-119.
Palincsar, A.S. (1998), “Social constructivist perspectives on teaching and learning”, *Annual Review of Psychology,* Vol. 49 No. 1, pp. 345-375.
Pampaka, M., Williams, J. and Hutcheson, G. (2012), “Measuring students’ transition into university and its association with learning outcomes”, *British Educational Research Journal,* Vol. 38 No. 6, pp. 1041-1071.
Pant, H.A., Stanat, P., Schroeders, U., Roppelt, A., Siegle, T. and Pöhlmann, C. (Eds.) (2013), *IQB-Ländervergleich 2012. Mathematische und naturwissenschaftliche Kompetenzen am Ende der Sekundarstufe I,* Waxmann, Münster.
Pappano, L. (2012), “The Year of the MOOC”, *The New York Times, Education Life Supplement* Nov 4, p. 26-26.
Pardo, A. and Kloos, C.D. (2011), “Stepping out of the box: towards analytics outside the learning management system”, in *Proceedings of the 1st International Conference on Learning Analytics and Knowledge, Banff,* pp. 163-167.
Parker, M. (2005), “Placement, Retention, and Success: A Longitudinal Study of Mathematics and Retention”, *Journal of General Education*, Vol. 54 No. 1, pp. 22-40.
Parsons, S.J. (2014), “Enabling success in mathematics and statistics. The effects of self-confidence and other factors in a University College”, Dissertation, Loughborough University, 2014.
Parsons, S.J., Croft, T. and Harrison, M. (2009), “Does students' confidence in their ability in mathematics matter?”, *Teaching Mathematics and its Applications,* Vol. 28 No. 2, pp. 52-68.
Pascale, C.-M. (2011), *Cartographies of Knowledge*, Sage, Thousand Oaks.
Pascarella, E.T. and Terenzini, P.T. (1991), *How college affects students: Findings and insights from twenty years of research*, Jossey-Bass, San Francisco.
Pask, G. (1976), “Styles and strategies of learning”, *British Journal of Educational Psychology*, Vol. 46 No. 2, pp. 128-148.
Patton, M.Q. (1990), *Qualitative evaluation and research methods,* Sage, Beverly Hills.
Patton, M.Q. (2002), *Qualitative research and evaluation methods*, Sage, Thousand Oaks.
Peng, C.-Y.J., Lee, K.L. and Ingersoll, G.M. (2002), “An introduction to logistic regression analysis and reporting”, *Journal of Educational Research,* Vol. 96 No. 1, pp. 3-14.
Persike, M. and Friedrich, J.-D. (2016), *Lernen mit digitalen Medien aus Studierendenperspektive: Arbeitspapier 17, Hochschulforum Digitalisierung,* Berlin.
Phipps, R. and Merisotis, J. (1999), *What’s the difference? A review of contemporary research on the effectiveness of distance learning in higher education,* Washington, D. C.
Pierce, R., Stacey, K. and Barkatsas, A. (2007), “A scale for monitoring students’ attitudes to learning mathematics with technology”, *Computers & Education,* Vol. 48, pp. 285-300.
Pintrich, P.R. (1999), “The role of motivation in promoting and sustaining self-regulated learning”, *International Journal of Educational Research,* Vol. 31 No. 6, pp. 459-470.

Pintrich, P.R. (2000), “The role of goal orientation in self-regulated learning”, in Boekaerts, M., Pintrich, P.R. and Zeidner, M. (Eds.), *Handbook of self-regulation*, Academic Press, New York, NY, pp. 451-502.
Pintrich, P.R. (2002), “The Role of Metacognitive Knowledge in Learning, Teaching, and Assessing”, *Theory into practice,* Vol. 41 No. 4, pp. 219-225.
Pintrich, P.R. (2003), “A motivational science perspective on the role of student motivation in learning and teaching contexts”, *Journal of Educational Psychology*, Vol. 95 No. 4, pp. 667-686.
Pintrich, P.R. and de Groot, E.V. (1990), “Motivational and self-regulated learning components of classroom academic performance”, *Journal of Educational Psychology,* Vol. 82 No. 1, pp. 33-40.
Pintrich, P.R., Smith, D.A.F., Garcia, T. and McKeachie, W.J. (1991), *A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ),* Ann Arbor, Michigan.
Plant, E.A., Ericsson, K.A., Hill, L. and Asberg, K. (2005), “Why study time does not predict grade point average across college students: Implications of deliberate practice for academic performance”, *Contemporary Educational Psychology,* Vol. 30 No. 1, pp. 96-116.
Poinstingl, H., Mair, P. and Hatzinger, R. (2007), “Manual zum Softwarepackage eRm (extended Rasch modeling)”, available at: http://erm.r-forge.r-project.org/eRm_manual.pdf (accessed 20 January 2014).
Polaczek, C. and Henn, G. (2008), “Vergleichende Auswertung des Mathematik-Eingangstests”, report, Fachhochschule Aachen.
Poladian, L. (2013), “Engaging life-sciences students with mathematical models: does authenticity help?”, *International Journal of Mathematical Education in Science and Technology,* Vol. 44 No. 6, pp. 865-876.
Preißler, I., Müller, R., Hammerschmidt, J. and Scholl, S. (2010), “Treibstoff für die Ingenieurausbildung - fachübergreifende Didaktik”, *Zeitschrift für Hochschulentwicklung,* Vol. 5 No. 3, pp. 105-115.
Prensky, M. (2001), “Digital Natives, Digital Immigrants”, *On the Horizon,* Vol. 9 No. 5.
Prenzel, M. and Baumert, J. (Eds.) (2008), *Vertiefende Analysen zu PISA 2006: Zeitschrift für Erziehungswissenschaft, Sonderheft 10*.
Pressley, M., Borkowski, J.G. and Schneider, W. (1989), “Good information processing: What it is and how education can promote it”, *Journal of Educational Research No.* 2, pp. 857-867.
Price, S. and Oliver, M. (2007), “A Framework for Conceptualising the Impact of Technology on Teaching and Learning”, *Educational Technology & Society,* Vol. 10 No. 1, pp. 16-27.
Punch, M. (1994), “Politics and ethics in qualitative research”, in Denzin, N.K. and Lincoln, Y.S. (Eds.), *Handbook of Qualitative Research*, Sage, Thousand Oaks, pp. 83-97.
Pustelnik, K. (2014), “Variables influencing the competencies of math first-year students at the university”, in Oesterle, S., Nicol, C., Liljedahl, P. and Allan, D. (Eds.), *Proceedings of the Joint Meeting of PME 38 and PME-NA 36*, p. 210-210.
R V 3.4.3, *R Version 3.4.3: R: A language and environment for statistical computing*, R Development Core Team, Vienna.
Rach, S. and Heinze, A. (2017), “The Transition from School to University in Mathematics: Which Influence Do School-Related Variables Have?”, *International Journal of Science and Mathematics Education*, Vol. 15 No. 7, pp. 1343-1363.

Rasch, G. (1960), *Probabilistic Models for Some Intelligence and Attainment Tests*, Reprint 1980, University of Chicago Press, Paedagogike Institut, Copenhagen.
Reddy, A. (2002), “E-learning ROI Calculations”, Business Source Premier, *e-learning magazine*, Vol. 3 No. 1, pp. 30-34.
Reiss, M.J., Hoyles, C., Mujtaba, T., Riazi-Farzad, B., Rodd, M., Simon, S. and Stylianidou, F. (2011), “Understanding Participation rates in post-16 Mathematics and Physics. Conceptualising and operationalising the UPMAP Project”, *International Journal of Science and Mathematics Education*, Vol. 9 No. 2, pp. 273-302.
Renkl, A. and Atkinson, R.K. (2003), “Structuring the Transition From Example Study to Problem Solving in Cognitive Skill Acquisition: A Cognitive Load Perspective”, *Educational Psychologist*, Vol. 38 No. 1, pp. 15-22.
Richardson, F.C. and Suinn, R.M. (1972), “The mathematics anxiety rating scale: Psychometric data”, *Journal of Counseling Psychology*, Vol. 19 No. 6, pp. 551-554.
Richardson, J.T.E., Morgan, A. and Woodley, A. (1999), “Approaches to Studying in Distance Education”, *Higher Education*, Vol. 37, pp. 23-55.
Richardson, M., Abraham, C. and Bond, R. (2012), “Psychological Correlates of University Students' Academic Performance: A Systematic Review and Meta-Analysis”, *Psychological Bulletin*, Vol. 138 No. 2, pp. 353-387.
Richey, R.C., Klein, J.D. and Nelson, W.A. (2004), “Developmental research: Studies of instructional design and development”, in Jonassen, D.H. (Ed.), *Handbook of Research for Educational Communications and Technology*, Lawrence Erlbaum, Mahwah, NJ, pp. 1099-1130.
Ridley, D.R., Bailey, B.L., Davies, E.S., Hash, S.G. and Varner, D.A. (1997), “Evaluating the impact of on-line course enrollments on FTEs at an urban university”, in *Annual forum of the Association for Institutional Research AIR, Orlando, FL*.
Rieber, L.P. (1996), “Seriously Considering Play: Designing Interactive Learning Environments Based on the Blending of Microworlds, Simulations, and Games”, *Educational Technology Research and Development*, Vol. 44 No. 2, pp. 43-58.
Riel, M. (2016), “Understanding Action Research”, available at: http://cadres.pepperdine.edu/ccar/define.html (accessed 26 May 2017).
Rijmen, F. (2010), *Measuring multidimensional latent growth*, Princeton, NJ.
Robbins, S.B., Lauver, K., Le, H., Davis, D., Langley, R. and Carlstrom, A. (2004), “Do psychosocial and study skill factors predict college outcomes? A meta-analysis”, *Psychological Bulletin*, Vol. 130 No. 2, pp. 261-288.
Roberts, M.J. and Newton, E.J. (2001), “Understanding strategy selection”, *International Journal of Human-Computer Studies*, Vol. 54 No. 1, pp. 137-154.
Robinson, C.L. and Croft, A.C. (2003), “Engineering students - diagnostic testing and follow up”, *Teaching Mathematics and its Applications*, Vol. 22 No. 4, pp. 177-181.
Robson, C. (2011), *Real World Research: A Resource for Users of Social Research Methods in Applied Settings*, 3rd ed., Wiley, Chichester.
Rodriguez, C.O. (2012), “MOOCs and the AI-Stanford like Courses: Two Successful and Distinct Course Formats for Massive Open Online Courses”, *European Journal of Open, Distance and E-Learning*.
Roegner, K., Seiler, R. and Timmreck, D. (2012), “E-xploratives Lernen an der Schnittstelle Schule/Hochschule. Didaktische Konzepte, Erfahrungen, Perspektiven”, available at: http://www.integral-learning.de/publications (accessed 21 January 2014).

Rogers, C.P., McEwen, M.R. and Pond, S. (2010), “The use of web analytics in the design and evaluation of distance education”, in Veletsianos, G. (Ed.), *Emerging technologies in distance education*, AU Press, Edmonton, pp. 231-247.

Röhrl, N., Haase, D. and Goll, C. (2013), “Integrierte Propädeutika am MINT-Kolleg Baden-Württemberg”, in Hoppenbrock, A., Schreiber, S., Göller, R., Biehler, R., Büchler, B., Hochmuth, R. and Rück, H.-G. (Eds.), *Mathematik im Übergang Schule / Hochschule und im ersten Studienjahr*, khdm report 2013, *Paderborn*, pp. 136-137.

Romero, C. and Ventura, S. (2010), “Educational Data Mining: A Review of the State of the Art”, *IEEE Transactions on systems, man, and cybernetics, Part C: Applications and reviews*, Vol. 40 No. 6, pp. 601-618.

Rooch, A., Kiss, C. and Härterich, J. (2014), “Brauchen Ingenieure Mathematik? Wie Praxisbezug die Ansichten über das Pflichtfach Mathematik verändert”, in Bausch, I., Biehler, R., Bruder, R., Fischer, P.R., Hochmuth, R., Koepf, W., Schreiber, S. and Wassong, T. (Eds.), *Mathematische Vor- und Brückenkurse*, Springer, Wiesbaden, pp. 389-409.

Rost, J. (1997), “Logistic Mixture Models”, in van der Linden, W.J. and Hambleton, R.K. (Eds.), *Handbook of Modern Item Response Theory*, Springer, New York, pp. 449-463.

Rost, J., Carstensen, C.H., Senkbeil, M. and Walter, O. (2005), *Bildungsmonitoring und Methodenforschung: Forschungsbericht 2003/2004*.

Russell, T.L. (2001), *The No Significant Difference Phenomenon: A Comparative Research Annotated Bibliography on Technology for Distance Education*, IDECC, Montgomery, AL.

Ryan, R.M. and Deci, E.L. (2000), “Self-determination theory and the facilitation of intrinsic motivation, social development, and well being”, *American Psychologist*, Vol. 55 No. 1, pp. 68-78.

Rylands, L., Simbag, V., Matthews, K.E., Coady, C. and Belward, S. (2013), “Scientists and mathematicians collaborating to build quantitative skills in undergraduate science”, *International Journal of Mathematical Education in Science and Technology*, Vol. 44 No. 6, pp. 834-845.

Sadler, R.D. (1989), “Formative Assessment and the Design of Instructional Systems”, *Instructional Science*, Vol. 18, pp. 119-144.

Sälzer, C., Reiss, K., Schiepe-Tiska, A., Prenzel, M. and Heinze, A. (2013), “Zwischen Grundlagenwissen und Anwendungsbezug: Mathematische Kompetenz im internationalen Vergleich”, in Prenzel, M., Sälzer, C., Klieme, E. and Köller, O. (Eds.), *PISA 2012. Fortschritte und Herausforderungen in Deutschland*, Waxmann, Münster, pp. 47-97.

Samson, P.J. (2015), “Can Student Engagement be Measured? and, if so, Does it Matter?”, in *Frontiers in Education Conference Conference Proceedings, El Paso, Texas, 21.-24.10.*

Sangrà, A., Vlachopoulos, D. and Cabrera, N. (2012), “Building an Inclusive Definition of E-Learning: An Approach to the Conceptual Framework”, *IRRODL THe International Review of Research in Open and Distance Learning*, Vol. 13 No. 2, pp. 146-159.

Sangwin, C. (2012), “Computer Aided Assessment of Mathematics using Stack”, in *12th International Congress on Mathematical Education COEX, Seoul, Korea, 8-15 July*.

Sangwin, C. (2013), *Computer Aided Assessment of Mathematics Using Stack*, Oxford University Press, Oxford.

Scanlan, J.O. (1985), “The role of mathematics in engineering education. An engineer's view”, *International Journal of Mathematical Education in Science and Technology*, Vol. 16 No. 3, pp. 445-451.
Schiefele, U. and Wild, K.P. (1994), “Lernstrategien im Studium: Ergebnisse zur Faktorenstruktur und Reliabilität eines neuen Fragebogens”, *Zeitschrift für Differentielle und Diagnostische Psychologie*, Vol. 15 No. 4, pp. 185-200.
Schmeck, R.R. and Ribich, F.D. (1978), “Construct Validation of the Inventory of Learning Processes”, *Applied Psychological Measurement*, Vol. 2 No. 4, pp. 551-562.
Schmidt, U., Altfeld, S., Schulze, K., Heinzelmann, S., Faaß, M. and Costa André, K.d. (2016), *Evaluation des Bund-Länder-Programms für bessere Studienbedingungen und mehr Qualität in der Lehre (Qualitätspakt Lehre)*, Berlin.
Scholes, V. (2016), “The ethics of using learning analytics to categorize students on risk”, *Educational Technology Research and Development*, Vol. 64 No. 5, pp. 939-955.
Schreiner, C. and Sjøberg, S. (2004), “Sowing the seeds of ROSE. Background, rationale, questionnaire development and data collection for ROSE (The Relevance of Science Education). A comparative study of students’ views of science and science education”, *Acta Didactica No.* 4, pp. 1-120.
Schulmeister, R. (1996), *Grundlagen hypermedialer Lernsysteme: Theorie - Didaktik - Design*, Addison-Wesley, Bonn.
Schumacher, C. and Ifenthaler, D. (2018), “Features students really expect from learning analytics”, *Computers in Human Behavior*, pp. 394-407.
Schwandt, T. (2006), “Opposition redirected”, *International Journal of Qualitative Studies in Education*, Vol. 19 No. 6, pp. 803-810.
Schwenk, A. and Berger, M. (2006), “Zwischen Wunsch und Wirklichkeit: Was können unsere Studienanfänger?”, *Die Neue Hochschule No.* 2, pp. 36-40.
SEFI mathematics working group (2013), *A Framework for Mathematics Curricula in Engineering Education*, Brussels.
Sharp, J.E. (2002), “Teaching teamwork communication with Kolb learning style theory”, in *FIE 2001 Reno: 31st Annual Frontiers in Education Conference impact on engineering and science education conference proceedings John Ascuaga's Nugget Casino Resort, Reno, Nevada, October 10-13, 2001, Reno, NV, USA, 10-13 Oct. 2001*, IEEE, Piscataway, N.J., F2C-1-2.
Shavelson, R.J., Young, D.B., Ayala, C., Brandon, P.R., Furtak, E.M., Ruiz-Primo, M.A., Tomita, M.K. and Yin, Y. (2008), “On the impact of curriculum-embedded formative assessment on learning: A collaboration between curriculum and assessment developers”, *Applied measurement in education No.* 21, pp. 295-314.
Shaw, C.T. and Shaw, V.F. (1997), “Attitudes of first-year engineering students to mathematics - A case study”, *International Journal of Mathematical Education in Science and Technology*, Vol. 28 No. 2, pp. 289-301.
Shaw, C.T. and Shaw, V.F. (1999), “Attitudes of engineering students to mathematics a comparison across universities”, *International Journal of Mathematical Education in Science and Technology*, Vol. 30, pp. 47-63.
Siemens, G. (2004), “Connectivism: A Learning Theory for the Digital Age”, available at: http://www.itdl.org/journal/jan_05/article01.htm (accessed 12 March 2018).

Simpson, M.L., Hynd, C.R., Nist, S.L. and Burrell, K.I. (1997), "College Academic Assistance Programs and Practices", *Educational Psychology Review,* Vol. 9 No. 1, pp. 39-87.
Skinner, B.F. (1954), "The science of learning and the art of teaching", *Harvard Educational Review,* Vol. 24, pp. 86-97.
Smith, G.G. and Ferguson, D. (2005), "Student attrition in mathematics e-learning", *Australasian Journal of Educational Technology,* Vol. 21 No. 3, pp. 323-334.
SPSS V 23, *SPSS Version 23: Statistics for Windows*, IBM Corp., Armonk, NY.
Stage, F. and Kloosterman, P. (1995), "Gender, Beliefs, and Achievement in Remedial College-Level Mathematics", *The Journal of Higher Education,* Vol. 66 No. 3, pp. 294-311.
Stake, R.E. (1975), *Evaluating the arts in education*, Merrill, Columbus.
Stake, R.E. (1994), "Case Studies", in Denzin, N.K. and Lincoln, Y.S. (Eds.), *Handbook of Qualitative Research,* Sage, Thousand Oaks, pp. 236-247.
Statistisches Bundesamt (2012), *Bildung und Kultur. Schnellmeldungsergebnisse der Hochschulstatistik zu Studierenden und Studienan-fänger/-innen, vorläufige Ergebnisse 2011/2012*, Wiesbaden.
Statistisches Bundesamt (2014), *Bildung und Kultur. Studierende an Hochschulen: Wintersemester 2013/2014, Fachserie,* Wiesbaden.
Stevens, A. (2003), "The Calculess Engineer!", *MSOR Connections,* Vol. 3 No. 4, p. 8-8.
Stieha, V., Shadle, S.E. and Paterson, S. (2016), "Stirring the Pot: Supporting and Challenging General Education Science, Technology, Engineering, and Mathematics Faculty to Change Teaching and Assessment Practice", *Journal of General Education,* Vol. 65 No. 2, pp. 85-109.
Straka, G.A. (2005), *Von der Klassifikationvon Lernstrategien im Rahmen selbstgesteuerten Lernens zur mehrdimensionalen und regulierten Handlungsepisode, ITB Forschungsberichte*, Bremen.
Street, H. (2010), "Factors Influencing a Learner's Decision to Drop-Out or Persist in Higher Education Distance Learning", *Online Journal of Distance Learning Administration*, Vol. 13 No. 4.
Stringer, E.T. (2007), *Action Research,* 3rd ed., Sage, Thousand Oaks.
Strobl, C. (2012), *Das Rasch Modell. Eine verständliche Einführung für Studium und Praxis, Sozialwissenschaftliche Forschungsmethoden*, Vol. 2, Rainer Hampp, München, Mering.
Sweller, J. (2005), "Implications of cognitive load theory for multimedia learning", in Mayer, R.E. (Ed.), *The Cambridge handbook of multimedia learning,* Cambridge University Press, New York, pp. 19-30.
Sweller, J., van Merriënboer, J.G. and Paas, F.G. (1998), "Cognitive architecture and instructional design", *Educational Psychology Review,* Vol. 10 No. 2, pp. 251-296.
Tabachnick, B.G. and Fidell, L.S. (2014), *Using multivariate statistics,* 6th ed., Pearson Education, Harlow.
Tallent-Runnels, M.K., Thomas, J., Lan, W.Y., Cooper, S., Ahern, T.C., Shaw, S.M. and Liu, X. (2006), "Teaching Courses Online: A Review of the Research", *Review of Educational Research,* Vol. 76 No. 1, pp. 93-135.
Tapia, M. and Marsh, G.E. (2004), "An Instrument to Measure Mathematics Attitudes", *Academic Exchange Quarterly,* Vol. 8 No. 2.
Tariq, V.N. (2013), "Quantitative skills in science", *International Journal of Mathematical Education in Science and Technology*, Vol. 44 No. 6, pp. 779-781.

Tashakkori, A. and Teddlie, C. (2009), "Integrating Qualitative and Quantitative Approaches to Research", in Bickman, L. and Rog, D.J. (Eds.), *The Sage handbook of applied social research methods*, Sage, Los Angeles, pp. 283-317.

Tashakkori, A. and Teddlie, C. (2010), "Overview of contemporary issues in mixed methods research", in Tashakkori, A. and Teddlie, C. (Eds.), *Sage Handbook of Mixed Methods in Social & Behavioral Research*, Sage, London, pp. 1-44.

Tempelaar, D.T., Rienties, B. and Giesbers, B. (2015), "In search for the most informative data for feedback generation: Learning analytics in a data-rich context", *Computers in Human Behavior*, Vol. 47, pp. 157-167.

Thiessen, V. and Blasius, J. (2008), "Mathematics achievement and mathematics learning strategies: Cognitive competencies and construct differentiation", *International Journal of Educational Research*, Vol. 47 No. 6, pp. 362-371.

Thomas, L. (2012), *Building student engagement and belonging in Higher Education at a time of change: Final report from the What Works? Student Retention & Success programme*, London.

Tolciu, A. and Sode, M. (2011), *Mehr Studienanfänger: Mehr Studienabbrecher?, HWWI policy paper*, Hamburg.

Tolley, H. and Mackenzie, H. (2015), *Senior Management Perspectives on Mathematics and Statistics Support in Higher Education: SIGMA report*.

Tourangeau, R., Conrad, F.G. and Couper, M.P. (2013), *The Science of Web Surveys*, Oxford University Press.

Tynjälä, P., Salminen, R.T., Sutela, T., Nuutinen, A. and Pitkänen, S. (2005), "Factors related to study success in engineering education", *European Journal of Engineering Education*, Vol. 30 No. 2, pp. 221-231.

UK Data Service (2013), "Create and manage data: anonymisation", available at: http://ukdataservice.ac.uk/manage-data/legal-ethical/anonymisation.aspx (accessed 1 May 2018).

van Barneveld, A., Arnold, K.E. and Campbell, J.P. (2012), "Analytics in Higher Education: Establishing a Common Language".

van den Bogaard, M. (2012), "Explaining student success in engineering education at Delft University of Technology: a literature synthesis", *European Journal of Engineering Education*, Vol. 37 No. 1, pp. 59-82.

van der Linden, W.J. and Hambleton, R.K. (1997), "Item Response Theory: Brief History, Common Models, and Extensions", in van der Linden, W.J. and Hambleton, R.K. (Eds.), *Handbook of Modern Item Response Theory*, Springer, New York, pp. 1-28.

van Eck, R. (2006), "Digital Game- Based Learning. It's Not Just the Digital Natives Who Are Restless", *Educause review*, Vol. 41 No. 2, pp. 16-30.

van Soom, C. and Donche, V. (2014), "Profiling First-Year Students in STEM Programs Based on Autonomous Motivation and Academic Self-Concept and Relationship with Academic Achievement", *PLoS one*, Vol. 9 No. 11, e112489.

van Zwanenberg, N., Wilkinson, L.J. and Anderson, A. (2000), "Felder and Silverman's Index of Learning Styles and Honey and Mumford's Learning Styles Questionnaire: How do they compare and do they predict academic performance?", *Educational Psychology*, Vol. 20 No. 3, pp. 365-380.

Vandecandelaere, M., Speybroeck, S., Vanlaar, G., Fraine, B. de and van Damme, J. (2012), "Learning environment and students' mathematics attitude", *Studies in Educational Evaluation*, Vol. 38, pp. 107-120.

Venezia, A. and Jaeger, L. (2013), "Transitions from High School to College", *The Future of Children*, Vol. 23 No. 1, pp. 117-136.

Vermunt, J.D. (1996), “Metacognitive, cognitive and affective aspects of learning styles and strategies. A phenomenographic analysis”, *Higher Education*, Vol. 31, pp. 25-50.
Vermunt, J.D. and Van Rijswijk, F.A. (1988), “Analysis and development of students' skill in selfregulated learning”, *Higher Education*, Vol. 17 No. 6, pp. 647-682.
Vogt, C.M. (2008), “Faculty as a Critical Juncture in Student Retention and Performance in Engineering Programs”, *Journal of Engineering Education*, Vol. 97 No. 1, pp. 27-36.
Vuik, K., Daalderop, F., Daudt, J. and van Kints, R. (2012), *Evaluation MUMIE - Online Math Education: Aerospace Engineering and Computer Science 2011-2012*.
Vygotsky, L.S. (1978), *Mind in society. The Development of Higher Psychological Processes*, Harvard University Press, Cambridge, MA.
Wagner, P. and Spiel, C. (2002), “Hausaufgabenforschung - ein Plädoyer für eine stärkere theoretische Verankerung”, *Empirische Pädagogik*, Vol. 16 No. 3, pp. 275-284.
Walford, G. (2005), “Research ethical guidelines and anonymity”, *International Journal of Research & Method in Education*, Vol. 28 No. 1, pp. 83-93.
Wang, A.Y. and Newlin, M.H. (2000), “Characteristics of students who enroll and succeed in web-based psychology classes” Journal of Educational Psychology, pp. 137-143.
Wang, M., Vogel, D. and Ran, W. (2011), “Creating a performance-oriented e-learning environment: A design science approach”, *Information & Management*, Vol. 48, pp. 260-269.
Watts, M. and Ebbutt, D. (1987), “More than the Sum of the Parts. Research methods in group interviewing”, *British Educational Research Journal*, Vol. 13 No. 1, pp. 25-34.
Wedelin, D., Adawi, T., Jahan, T. and Andersson, S. (2015), “Investigating and developing engineering students’ mathematical modelling and problem-solving skills”, *European Journal of Engineering Education*, Vol. 40 No. 5, pp. 557-572.
Weinstein, C.E., Acee, T.W. and Jung, J. (2011), “Self-regulation and learning strategies”, *New Directions for Teaching and Learning*, Vol. 126 No. 126, pp. 45-53.
Weinstein, C.E., Goetz, E.T. and Alexander, P.A. (Eds.) (1988a), *Learning and Study Strategies. Issues in Assessment, Instruction, and Evaluation*, Academic Press, San Diego, California.
Weinstein, C.E. and Mayer, R.E. (1986), “The teaching of learning strategies”, in Wittrock, M.C. (Ed.), *Handbook of research on teaching*, 3rd ed., Macmillan, New York, pp. 315-327.
Weinstein, C.E., Zimmermann, S.A. and Palmer, D.R. (1988b), “Assessing learning strategies. The design and development of the LASSI”, in Weinstein, C.E., Goetz, E.T. and Alexander, P.A. (Eds.), *Learning and Study Strategies. Issues in Assessment, Instruction, and Evaluation*, Academic Press, San Diego, California, pp. 25-40.
Wenger, E. (1998), *Communities of practice: learning, meaning, and identity: Learning in doing: social, cognitive and computational perspectives*, Cambridge University Press.
Whitelock, D.M. (2008), “Accelerating the assessment agenda: thinking outside the black box”, available at: http://oro.open.ac.uk/11912 (accessed 5 May 2012).

Wild, K.P. (2000), *Lernstrategien im Studium: Strukturen und Bedingungen*, Waxmann, Münster.
Wildt, J. (2005), "E-Bologna: E-Learning im Kontext eines "Shift from teaching to learning"", in Kerres, M. and Keil-Slawik, R. (Eds.), *Hochschulen im digitalen Zeitalter: Innovationspotenziale und Strukturwandel: Education Quality Forum*, Münster/München/Berlin, pp. 203-214.
Winkelman, P. (2009), "Perceptions of mathematics in engineering", *European Journal of Engineering Education*, Vol. 34 No. 4, pp. 305-316.
Winne, P.H. (2004), "Students' calibration of knowledge and learning processes: Implications for designing powerful software learning environments", *International Journal of Educational Research*, Vol. 41 No. 6, pp. 466-488.
Winters, F.I., Greene, J.A. and Costich, C.M. (2008), "Self-regulation of learning within computer-based learning environments: A critical analysis", *Educational Psychology Review*, Vol. 20 No. 4, pp. 429-444.
Witte, K. de, Haelermans, C. and Rogge, N. (2015), "The effectiveness of a computer-assisted math learning program", *Journal of Computer Assisted Learning*, Vol. 31 No. 4, pp. 314-329.
Wittwer, J. and Renkl, A. (2008), "Why instructional explanations often do not work. A framework for understanding the effectiveness of instructional explanations", *Educational Psychologist*, Vol. 43, pp. 49-64.
Wright, B.D. and Mok, M.M.C. (2004), "An Overview of the Family of Rasch Measurement Models", in Smith, E.V. and Smith, R.M. (Eds.), *Introduction to Rasch Measurement: Theory, Models, and Applications*, Jampress.
Wu, M.L., Adams, R.J. and Wilson, M.R. (1997), *ConQuest: Multi-Aspect Test Software*, Australian Council for Educational Research, Camberwell.
Wu, M.L., Adams, R.J., Wilson, M.R. and Haldane, S.A. (Eds.) (2007), *ACER ConQuest version 2.0. Generalised item response modelling software*, Acer Press.
Xie, Y. and Shauman, K.A. (2005), *Women in science. Career processes and outcomes*, Harvard University Press, Cambridge, MA.
Yamamoto, K. and Kulick, E. (2000), "Scaling Methodology and Procedures for the TIMSS Mathematics and Science Scales", in Martin, M.O., Gregory, K.D. and Stemler, S.E. (Eds.), *TIMSS 1999 technical report*, Boston College, Chestnut Hill, pp. 237-264.
Yang, J.C., Quadir, B., Chen, N.-S. and Miao, Q. (2016), "Effects of online presence on learning performance in a blog-based online course", *The Internet and Higher Education*, Vol. 30, pp. 11-20.
Yen, W.M. and Fitzpatrick, A.R. (2006), "Item Response Theory", in Brennan, R.L. (Ed.), *Educational Measurement*, Praeger, Westport, pp. 111-153.
Yin, R.K. (2003), *Applications of Case Study Research, Applied Social Research Methods*, Vol. 34, Sage, Thousand Oaks.
Yin, R.K. (2009), *Case Study Research. Design and Methods*, Sage, Thousand Oaks.
Yorke, M. and Longden, B. (2008), *The first-year experience of higher education in the UK: Final report*, York.
Young, C.Y., Georgiopoulos, M., Hagen, S.C., Geiger, C.L., Dagley-Falls, M.A., Islas, A.L., Ramsey, P.J., Lancey, P.M., Straney, R.A., Forde, D.S. and Bradbury, E.E. (2011), "Improving student learning in calculus through applications", *International Journal of Mathematical Education in Science and Technology*, Vol. 42 No. 5, pp. 591-604.

Zacharis, N.Z. (2015), “A multivariate approach to predicting student outcomes in web-enabled blended learning courses”, *Internet and Higher Education*, Vol. 27, pp. 44-53.
Zemsky, R. and Massy, W.F. (2004), “Thwarted innovation: What happened to e-learning and why”, Learning Alliance at the University of Pennsylvania, available at: http://immagic.com/eLibrary/ARCHIVES/GENERAL/UPENN_US/P040600Z.pdf (accessed 23 January 2014).
Zhang, G., Anderson, T.J., Ohland, M.W. and Thorndyke, B.R. (2004), “Identifying factors influencing engineering student graduation: A longitudinal and crossinstitutional study”, *Journal of Engineering Education*, Vol. 93, pp. 313-320.
Zimmerman, B.J. (1989a), “A social cognitive view of self-regulated academic learning”, *Journal of Educational Psychology*, Vol. 81 No. 3, pp. 329-339.
Zimmerman, B.J. (1989b), “Models of self-regulated learning and academic achievement”, in Zimmerman, B.J. and Schunk, D.H. (Eds.), *Self-regulated learning and academic achievement: Theory, research and practice*, Springer, New York, NY, pp. 1-26.
Zimmerman, B.J. (2002), “Becoming a self-regulated learner: An Overview”, *Theory into practice*, Vol. 41 No. 2, pp. 64-70.
Zimmerman, B.J. and Moylan, A. (2009), “Self-Regulation: Where Metacognition and Motivation Intersect”, in Hacker, D.J. (Ed.), *Handbook of Metacognition in Education*, Routledge, New York, pp. 299-316.
Zimmerman, B.J., Moylan, A., Hudesman, J., White, N. and Flugman, B. (2011), “Enhancing self-reflection and mathematics achievement of at-risk urban technical college students”, *Psychological Test and Assessment Modeling*, Vol. 53 No. 1, pp. 141-160.

# List of Appendices


## A Publications

1-14 Publications and paper presentations

## B Descriptive data

B.1 Pre- and main study (2011-2016)

B.2 Main study (2014): Course types

## C Quantitative tools: pre-posttest design

C.1 Pre-test items

C.2 Post-test items

## D Surveys

D.1 Demographic and personal variables

D.2 Self-reports on mathematical areas

D.3 Attitude towards mathematics

D.4 Evaluation questionnaire

D.5 Learning strategies scale

## E Pre-study: group interviews

E.1 Group interviews 2012

E.2 Group interviews 2013

E.3 Guiding questions

E.4 Extract: group interview statements

## F Quantitative analyses

F.1 Relations between exam scores and cumulated GPA (2011)

F.2 Mathematics I performance pre-course participants versus non-participants (2011-2016)

F.3 Multiple regressions with Mathematics I (2011-2016)

## G First year student interviews

G.1 Guiding questions

G.2 Interview summaries

G.3 Categorisations

# A Publications

1 Derr, K.; Hübl, R.; Ahmed, M.Z. (2018). Prior knowledge in mathematics and study success in engineering. Informational value of learner data collected from a web-based pre-course. European Journal of Engineering Education 10 (3), pp. 1–16. DOI: 10.1080/03043797.2018.1462765

2 Derr, K. (2017). Identifying Consistent Variables in a Heterogeneous Data Set: Evaluation of a Web-Based Pre-Course in Mathematics. Electronic Journal of e-Learning EJEL 15 (1), pp. 82–93. ERIC Number: EJ1140127

3 Derr, K.; Hübl, R.; Mechelke-Schwede, E.; Podgayetskaya, T., Weigel, M. (2017): "Predicting study success in engineering? Evaluation of learner data" (Original title: Vorhersage von Studienerfolg in den Ingenieurwissenschaften über Learning Analytics? Aussagekraft von Lernerdaten in einem webbasierten Mathematik-Vorkurs. In U. Kortenkamp and A. Kuzle (eds.): Beiträge zum Mathematikunterricht, WTM, Münster, pp. 1297–1300. DOI: http://dx.doi.org/10.17877/DE290R-18569

4 Derr, K.; Hübl, R.; Podgayetskaya, T. (2016): "Potential and limitations to the use of formative e-assessment and automated feedback in online pre-courses" (Original title: Formatives eAssessment in Online-Brückenkursen: Potentiale und Grenzen und die Rolle des Feedback). In: Institut für Mathematik und Informatik der Pädagogischen Hochschule Heidelberg (eds.): Beiträge zum Mathematikunterricht, WTM, Münster, pp. 1145–1148. DOI: http://dx.doi.org/10.17877/DE290R-17587

5 Derr, K.; Jeremias, X.V.; Schäfer, M. (2016). "(e)-bridging courses in mathematics: best practice reports from three universities" (Original title: Optimierung von E-Brückenkursen Mathematik: Beispiele von drei Hochschulen). In A. Hoppenbrock et al. (eds.). *Lehren und Lernen von Mathematik in der Studieneingangsphase*. Springer Spektrum, Berlin, pp. 115–129. ISBN: 978-3-658-10261-6

6 Derr, K.; Hübl, R.; Ahmed, M.Z. (2015). "Using test data for successive refinement of an online pre-course in mathematics". Proceedings 14th European Conference on e-Learning ECEL 2015, 29-30 October, Hatfield, pp. 173-180. ISBN: 978-1-910810-70-5

7 Derr, K.; Hübl, R.; Podgayetskaya, T. (2015). "Development of a web-based pre-course in mathematics based on formative evaluation" (Original title: Formative Evaluation und Datenanalysen als Basis zur schrittweisen Optimierung eines Online Vorkurses Mathematik). In: N. Nistor and S. Schirlitz (eds.), *Digitale Medien und Interdisziplinarität; Medien in der Wissenschaft*, Band 68, Waxmann, Münster, pp. 186-196. DOI: urn:nbn:de:0111-pedocs-113198

8 Derr, K.; Hübl, R.; Podgayetskaya, T. (2015). "Online assistance in mathematics pre-courses: domain-related and interdisciplinary aspects" (Original title: Betreuungs-konzepte für Online-Vorkurse in Mathematik: Fachliche und überfachliche Aspekte). Proceedings 2nd HD-MINT-Symposium, 24-25 September 2015, Nuremberg, pp. 64-69. ISSN: 1612-4537

9 Derr, K.; Hübl, R.; Podgayetskaya, T. (2015). "Online support in a pre-course in mathematics: approaches to addressing heterogenic groups" (Original title: Betreuungsangebote in einem Online Vorkurs Mathematik: Modularisierung als Antwort auf heterogene Studierendenschaft?). In: F. Caluori, H. Linneweber-Lammerskitten and C. Streit (eds.): Beiträge zum Mathematikunterricht, WTM, Münster, pp. 228–231. DOI: https://doi.org/10.17877/de290r-16618

10 Derr, K.; Hübl, R. (2014) “Online pre-courses in mathematics” (Original title: Mathematik Studienvorbereitung Online für technische Studiengänge). In P. Morschheuser (ed.) Qualifizierung von Studierenden im Student-Life-Cycle, Proceedings Mosbacher Tag der Lehre, 23rd October 2015, Mosbach, pp. 104-109.

11 Derr, K.; Hübl, R. (2013) “Self-study university preparation in mathematics: didactical aspects of self-assessment” (Original title: Mathematik-Studienvorbereitung im Selbststudium: Didaktische Aspekte des Selbst-Assessment). Proceedings 1st HD-MINT-Symposium, 7-8 November 2013, Nuremberg, pp. 138-143. ISSN: 1612-4537

12 Derr, K.; Hübl, R.; Ahmed, M.Z. (2013). “Web-based tests and learning material for study-preparation in mathematics for engineering programmes” (Original title: Online–Selbsttests und -Lernmaterialien zur Studienvorbereitung Mathematik) 2nd khdm-conference Mathematik im Übergang Schule / Hochschule und im ersten Studienjahr, 20-23 February 2013, University of Paderborn.

13 Derr, K.; Hübl, R.; Ahmed, M.Z. (2012). “University preparation via self-e-assessment & self-study: first findings and implications from evaluating an e-learning-platform”. Proceedings of ECEL 2012, 11th European Conference on e-learning, 26-27 October 2012, University of Groningen. ISBN: 978-1-908272-74-4

14 Derr, K.; Hübl, R. (2012). “Online preparatory courses in Mathematics: Self-study courses for prospective students in engineering” (Original title: Studienvorbereitung Mathematik Online: Ein Selbstlernangebot für Studienanfänger/-innen in technischen Studiengängen). In: M. Ludwig and M. Kleine (eds Beiträge zum Mathematikunterricht, WTM, Münster, pp. 189–192. DOI: http://dx.doi.org/10.17877/DE290R-8000

A.1 Derr, K.; Hübl, R.; Ahmed, M.Z. (2018). Prior knowledge in mathematics and study success in engineering. Informational value of learner data collected from a web-based pre-course. European Journal of Engineering Education 10 (3), pp. 1–16.

DOI: 10.1080/03043797.2018.1462765

https://www.tandfonline.com/eprint/FZsFXabyQpGWyV7FjWTF/full

EUROPEAN JOURNAL OF ENGINEERING EDUCATION, 2018
https://doi.org/10.1080/03043797.2018.1462765



# Prior knowledge in mathematics and study success in engineering: informational value of learner data collected from a web-based pre-course

Katja Derr[a], Reinhold Hübl[a] and Mohammed Zaki Ahmed[b]

[a]Optes Project, Baden-Wuerttemberg Cooperative State University Mannheim, Mannheim, Germany; [b]School of Computing, Electronics and Mathematics, Faculty of Science & Engineering, Plymouth University, Plymouth, UK

**ABSTRACT**

The article describes the development and evaluation of a web-based pre-course in mathematics, delivered to four cohorts of engineering students at a German university. Based on demographic, personal, and learning-related data relationships between students' preconditions, their learning gains in the pre-course, and study success in the degree programme were analysed. The results support the existing literature in that domain-related prior knowledge and secondary school achievement play a dominant role regarding study success in engineering. The analyses also showed that the influence of cognitive predictors could only be compensated for by a strong learner engagement. At-risk students with high pre-course learning gains showed significantly better first-year performance. The number of self-tests a student attempted was positively related to pre-course learning gains and even to first-year performance, suggesting that this variable is a good indicator of student engagement.

**ARTICLE HISTORY**
Received 31 May 2017
Accepted 4 April 2018

**KEYWORDS**
Entry test; formative evaluation; mathematics education; pre-course; web-based learning

## 1. Introduction and background

One major characteristic of the transition from secondary to tertiary education today is a high heterogeneity in students' basic skills and knowledge. Particularly in mathematics, many first-year students have considerable gaps; this even applies to freshmen in STEM subjects. Long-term observations of first-year students' knowledge suggest increasing deficits in techniques like rearranging fractions, the application of power and logarithm rules, or the identification of basic functions (Crowther, Thompson, and Cullingford 1997; Lawson 2000; Faulkner, Hannigan, and Gill 2010). The 'mathematics problem' was first addressed in 1995 in the United Kingdom (Howson et al. 1995) but has been subject to discussion in other European countries as well (e.g. Engineering Council 2000). The 'decline', or increase in heterogeneity, may to some extent be related to a growing number of students entering tertiary education (HEFCE 2013). In Germany, for example, the rate of students proceeding to university has grown from 34% in 2000 to 58% in 2014 (see report Federal Statistical Office 2016). The differing knowledge levels of German students have also been ascribed to different types of secondary schools and an increase of 'non-traditional' students (Polaczek and Henn 2008), to differing populations and educational policies in German federal states (Pant et al. 2013), and to a revised secondary school curriculum (Knospe 2011).

From a student's point of view, knowledge gaps in mathematics can be considered a risk factor regarding study success. To close secondary school gaps and at the same time keep up with an

**CONTACT** Katja Derr katja.derr@dhbw-mannheim.de

already demanding schedule puts a high strain on their first year at university. Accordingly, the demand for preparatory and bridging courses in mathematics has grown considerably; today, nearly all science and engineering faculties in Germany (and a growing number of business faculties) provide additional mathematics support (Bargel 2015).

In this article, data collected from a web-based pre-course in mathematics administered to four cohorts of prospective engineering students at Baden-Wuerttemberg Cooperative State University (DHBW) Mannheim are reported. Prior achievement, results in a pre-test in mathematics, pre-course learning gains, and a set of demographic and personal data were analysed regarding their impact on subsequent achievement.

### *1.1. Predictors of study success*

Factors influencing academic achievement have been investigated comprehensively in educational psychology. Amid the digitalisation process in higher education, there also has been a growing interest in learning analytics. Educational data are harvested in order to identify students who are at risk to fail their courses and to suggest interventions at an early stage (Huang and Fang 2013; Marbouti, Diefes-Dux, and Strobel 2015; Sclater, Peasgood, and Mullan 2016).

It is generally agreed upon that secondary and tertiary achievement are strongly related to each other (Harackiewicz et al. 2002; Kuncel and Hezlett 2007; Trapmann et al. 2007). Secondary school grades (leaving certificates, GCSE, or grade point average, GPA), for example, have been found valid predictors of tertiary GPA and of student retention in general, and in particular in STEM subjects (Hell, Linsner, and Kurz 2008; Kokkelenberg and Sinha 2010; Söderlind and Geschwind 2017). For students with a high level of domain-related prior knowledge, it comes easier to acquire new knowledge; thus, in technical degree programmes, mathematics grades (Faulkner, Hannigan, and Gill 2010; Hall et al. 2015) or mathematics placement test scores have also been found predictive of later study success (Zhang et al. 2004; Ehrenberg 2010; Faulkner, Hannigan, and Gill 2010; Greefrath, Koepf, and Neugebauer 2016). The literature also suggests a higher risk for students who attended a vocational school and for students with non-traditional backgrounds (Faulkner, Hannigan, and Fitzmaurice 2014; van Soom, Donche, and Costa 2014).

Although a dominant influence of cognitive variables can be stated, affective and metacognitive variables are considered influential, as well. Students' attitudes towards a subject are likely to impact their motivation to learn. It also could be shown that attitudes correlate with students' confidence and self-beliefs (Pintrich and de Groot 1990; Meyer and Eley 1999). Methodologically, it has been found difficult to separate cognitive and motivational variables as students with a high level of prior knowledge are also more likely to have positive attitudes towards learning and to be efficient self-regulated learners.

In a multiple analysis on academic achievement in STEM, Ackerman, Kanfer, and Beier (2013) compared the impact of performance-related variables and a set of non-traditional trait complexes (personality, motivation, self-regulation, self-concept, self-estimates of ability). With an isolated $R^2$ of .21, mathematics placement test results had a particularly strong influence on tertiary GPA, whereas trait complexes in isolation accounted for 5–8%. With the complete model, 40% of the variance in cumulated GPA could be explained. Out of the five trait complexes, students' self-concepts in mathematics (their self-confidence and attitudes towards the subject) and their ability to master and organise learning most strongly contributed to predicting achievement in STEM.

Thus affective and metacognitive factors are likely to contribute to predictor models, but seldom outperform cognitive or school-related variables (Hailikari, Nevgi, and Komulainen 2008; Richardson, Abraham, and Bond 2012; Rach and Heinze 2017). To some extent, this effect may be ascribed to the difficulty to model non-traditional variables in a linear manner (Eley and Meyer 2004; Robbins et al. 2004). It also should be pointed out that even in strong models, a lot of variance remains unaccounted for; this particularly applies to the prediction of student withdrawal which is usually influenced by a multitude of factors (Besterfield-Sacre, Atman, and Shuman 1997; Heublein and Wolter 2011).

### 1.2. Study interest

(1) Based on the literature, a strong correlation between prior performance, domain-related prior knowledge, and study success in engineering is assumed. Can these relationships be reproduced with the data collected for this study and can we identify at-risk students?
(2) Which of the variables collected from the learning management system (LMS) deliver meaningful and consistent results? Which factors are most influential regarding learning gains of the at-risk group?
(3) Can pre-course data be related to study success in engineering? Did pre-course participation improve at-risk students' starting position?

## 2. Method

### 2.1. Project background

The study was conducted at the school of technology at DHBW Mannheim. The analyses reported in this article are based on data collected from four cohorts (first-year students 2011–2014; $N = 2967$) enrolled in five technical degree programmes (computer science, electrical engineering, mechanical engineering, mechatronics, and industrial engineering). Note that in this period of time, there was a school reform in some German federal states; secondary education was reduced from nine to eight years, resulting in higher numbers of students in 2012 and 2013.

For the analyses, pre-course learner data (test results, questionnaire responses, and log files) and data collected from the university's administration were available. In the privacy statement, students were informed on the background of the study and that all data would be anonymised for evaluation.

The first three years of the study were used to develop, evaluate, and modify the pre-course programme (see Derr, Hübl, and Ahmed 2015). In this paper, the focus will be on the pre-course results of the cohort of 2014 who participated in the revised programme as described in the following section.

### 2.2. Pre-course design

#### 2.2.1. Diagnostic pre-test in mathematics

The e-learning environment may be accessed in June. Pre-course participation is not mandatory but via the university's homepage and mailing lists, students are encouraged to (at the least) test their mathematics knowledge. The two-hour diagnostic self-test covers 10 mathematical fields (from Arithmetic to Vectors), each addressed by a set of items (total: 77 test items).

#### 2.2.2. Learning modules

After submitting the test, students receive a diagnostic feedback, suggesting learning contents if test results in a mathematical field are below 50%. Six out of the 10 learning modules cover the basic mathematics school curriculum and can be regarded as repetition (1 Arithmetic; 2 Equations; 3 Powers, roots, and logarithms; 4 Functions; 5 Geometry; and 6 Trigonometry), whereas 4 optional learning modules are only suggested for students who feel confident in the basic curriculum (Real numbers, Vectors, Continuous functions) or for students enrolled in computer science (Logic) (see also recommendations by SEFI Mathematics Working Group 2013; COSH 2014). The web-based learning contents provide texts, graphs, animations and videos, examples, and exercises. At the end of each module, students can take a subject-related self-assessment, consisting of 10–15 randomised items. Feedback to this test comprises a general feedback and detailed solutions for every problem.

#### 2.2.3. Additional support

Students who want additional support may enrol in week-long on-campus courses or a one-month e-tutoring course in September. All students have access to the same web-based learning material, but in the e-tutoring course, the learning process is structured and monitored by mathematics lecturers. The e-tutors help students to organise their learning, encourage them to discuss mathematical problems with peers, and give feedback to weekly uploaded exercise sheets.

#### 2.2.4. Post-test

The post-test is taken at the university's computer laboratories during the induction week. Both pre- and post-test items address the above-mentioned mathematical fields and are on the same difficulty level, but the post-test is much shorter (40 items and 1 hour time limit). The gain score, or difference between post-test and pre-test results, is interpreted as a measure of learning outcome. Note that the pre–post-test design underwent a thorough revision process from 2011 to 2013. Based on these cohorts' test results, item analyses were performed that helped to identify outlying or unfit items (for details, see Derr, Hübl, and Ahmed 2015). Pre–post-test similarity was established by comparing pre-test results with post-test results of students that had neither participated in the pre-test nor in the pre-course.

### 2.3. Data collection

#### 2.3.1. Dependent variables (study success)

Cumulated GPA at the end of the degree programme and the dichotomous variable retention (graduation = 1, withdrawal = 0) were available for the cohorts 2011 to 2013. In addition, the examination Mathematics I was identified as a first-year indicator of study success. In correlation analyses with final GPA, it outperformed all other first-year exams (2011: $r = .62$, $n = 660$; 2012: $r = .62$, $n = 776$; 2013: $r = .70$, $n = 665$; $p < .01$). By comparison, the exam Construction I (mechanical engineering) had a correlation coefficient between $r = .34$ and .36, whereas Physics had a correlation coefficient of $r = .57$. A simple linear regression model using Mathematics I as a predictor of GPA was also significant ($p < .01$) and explained up to 43% of the variance in GPA.

Mathematics I was also significantly related to retention in a binary logistic regression ($p < .01$), suggesting that students with poor performance in this exam were more likely to withdraw from the degree programme. This estimation generated many outlying values; thus, the model was less reliable than the linear regression with GPA. However, compared to other first-year exams, Mathematics I showed the strongest relation to overall study success and was considered a good early predictor of study success in engineering. This confirmed that Mathematics I could be used as dependent variable in the 2014 analyses.

#### 2.3.2. Independent variables (=preconditions)

Altogether eight independent variables describing students' preconditions when entering university were collected: demographic information (gender, age, gap between secondary and tertiary education, and state of origin), school-related variables (type of secondary school, secondary school GPA, and mathematics grades), and prior knowledge in mathematics (diagnostic pre-test results in per cent). It was hypothesised that all performance-related measures would strongly correlate with the dependent variables Mathematics I, cumulated GPA, and graduation (Figure 1).

Learning gains in the pre-course were represented by the difference between pre-test and post-test results. It was expected that pre-course participation would positively affect this gain score and that a high student engagement would correlate with this score.

It also was assumed that affective variables like attitude towards mathematics and mathematics learning would be influential; these were measured by two subscales from the 'Trends in International Mathematics and Science Study'. In the TIMSS subscale, 'liking mathematics' students' feelings

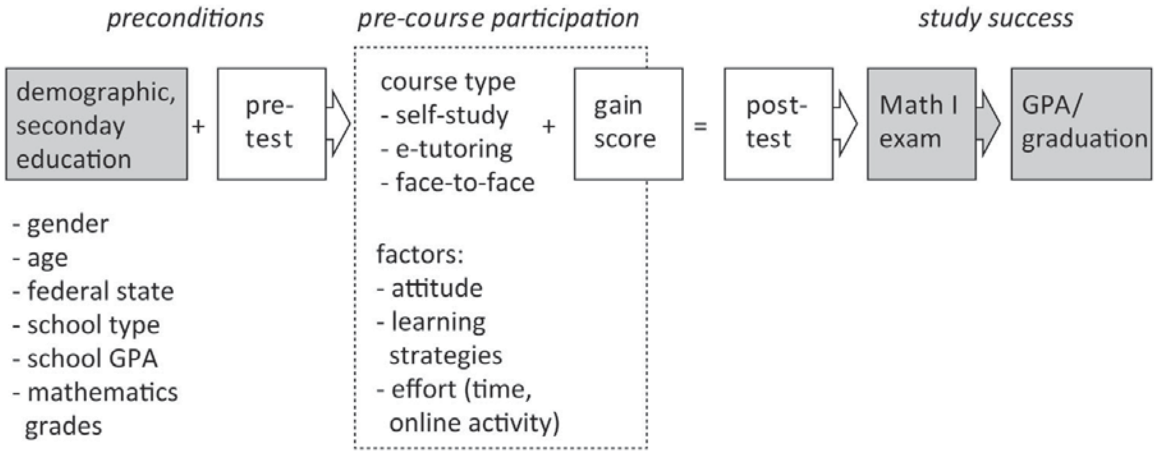



**Figure 1.** Overview of collected variables: preconditions, pre-course participation, and study success.

towards the subject are addressed, for example 'I am interested in mathematics' or 'I like learning mathematics'. The subscale 'self-confidence in learning mathematics' is represented by items like 'I learn things quickly in mathematics' (Kadijevich 2006, 41f; Mullis et al. 2012, 333f).

A second Likert scale was administered at the end of the pre-course, referring to students' use of learning strategies. The LIST inventory (Schiefele and Wild 1994) is a German adaptation of the 'Motivated Strategies for Learning Questionnaire MSLQ' (Pintrich et al. 1991). Seven items from the subsets 'Cognitive and metacognitive Strategies' and 'Resource management strategies' were revised to address pre-course participants' use of learning strategies (for example 'I always followed a certain learning schedule' from the subscale 'Time and study environment').

Students' effort and engagement in the learning process were also represented by self-reports and LMS log files: In the evaluation questionnaire, students answered how many learning modules they had studied and how much time per week they had learned. The log files informed on the number of learning module page views, the number of test attempts (randomised self-tests provided at the end of each module), and the number of forum posts (in the e-tutoring course). A proficient use of learning strategies and a high level of learner activity was expected to result in higher learning gains in the pre-course.

### *2.4. Sample*

In 2014, 84% of all first-year engineering students took both tests (diagnostic pre-test and post-test). For the analysis, these students were ascribed to the group of 'pre-course participants', regardless of their level of learning activity. About a third of all pre-course participants chose to enrol in at least one additional programme. One hundred and nineteen students participated in a week-long face-to-face course, and 113 students completed the one-month e-tutoring course with a certificate (attrition rate in this course was 14%). A group of 28 students attended both additional programmes.

The answer rate of the demographic questionnaire was close to 100% as these items were administered together with the pre-test. Evaluation answer rates were much lower; in the group of e-tutoring participants, 60% answered this questionnaire, but when looking at the whole group of pre-course participants, the answer rate was only 34%.

Of all first-year students, 98% participated in the post-test that was taken at the university's computer labs during induction week. For the regression analysis, data from 674 students who took the first-year examination Mathematics I six months later were available (Table 1).

### *2.5. Limitations*

E-learning environments have made course evaluation easier in many ways, with a multitude of learner data available for analysis. But not all collected data may deliver meaningful results. In

**Table 1.** Pre-course participation, collected data, and first-year students in 2014.

| | *N* |
|---|---|
| Pre-course participants (=pre-test *and* post-test participation) | 603 |
| Questionnaire I: personal and attitude scales | 593 |
| Self-study | 386 |
| + E-tutoring course | 85 |
| + Face-to-face course | 91 |
| + E-tutoring and face-to-face course | 28 |
| Questionnaire II: evaluation and learning strategies scales | 200 |
| Enrolled students | 722 |
| Post-test | 708 |
| Post-test only | 105 |
| First-year performance (Mathematics I) | 674 |

distance education, learner commitment has been found less consistent and students more often drop out, even after initially high interest (Smith and Ferguson 2005; Street 2010; Ashby, Sadera, and Mcnary 2011), an effect particularly observed in open access courses (Pappano 2012). Answer rates in web-based evaluations are often lower, making it difficult to identify reasons for withdrawal (Cook, Heath, and Thompson 2000; Fan and Yan 2010).

In this study, only online or self-reported learner behaviour could be monitored. Thus, students who chose to study with the help of peers, textbooks, or other resources and did not answer the evaluation had the same 'effort' scores as students who eventually did nothing.

It also should be considered that no randomised groups could be used. Due to ethical and organisational reasons, students were free to self-enrol in the different additional course programmes. As learner behaviour is likely to be related to performance measures, a bias will have to be accounted for in all interpretations.

Finally, it might also be discussed if graduation, cumulated GPA, or examination results are exhaustive measures of study success. For reasons of comparability, it seemed appropriate to use these widespread performance measures (Robbins et al. 2004, 262) although alternative approaches to measuring 'success' in an engineering degree programme are certainly conceivable.

## 3. Results

The results are reported alongside the three guiding questions (Section 1.2).

### *3.1. Basic model: students' preconditions and study success*

Linear and binary logistic regression analyses verified the assumptions made in Section 1.1. The two variables secondary school GPA and diagnostic pre-test results showed the strongest and most consistent impact on first- and final-year academic achievement, as well as graduation/withdrawal. Whereas secondary school GPA showed a stronger relation to overall study success, pre-test results had a stronger impact on first-year achievement: this variable alone accounted for 21% of the variance in Mathematics I.

According to the 2014 estimation, each increase in secondary school GPA (plus 1) was related to an increase in Mathematics I of plus .44. A step up in pre-test results (in per cent) was related to an increase in Mathematics I grades of .025. Thus, students with a pre-test mean score of 40 were predicted Mathematics I grades .5 above those of similar students with a pre-test mean score of 20. (Note that in Germany, GPA and Mathematics I grades range on a linear scale from 1 to 5; see also Table 5, model 1).

The type of secondary school attended was also found as an important factor, suggesting significantly poorer performance for students from vocational schools and for students with non-traditional backgrounds (Faulkner, Hannigan, and Fitzmaurice 2014; van Soom, Donche, and Costa 2014).

Mathematics grades at school were also related to Mathematics I, but in the multiple model, this variable showed less powerful results than expected (Zhang et al. 2004; Ehrenberg 2010; Faulkner, Hannigan, and Gill 2010). As pre-test results are also a measure of domain-related prior knowledge, they may have overpowered the impact of grades when added to the model.

Interactions between variables were identified for gender, age, and educational background. Female students, for example, often showed better first-year performance than male students, and in some models, this effect was significant. A descriptive analysis showed that women more often had traditional educational backgrounds and good or very good secondary school grades than male students. After controlling for these interactions, gender was no longer influential. In the literature, investigations of the relation between gender and performance in mathematics or science have led to mixed results (Zhang et al. 2004; Xie and Shauman 2005; Johnson and Kuennen 2006; Richardson, Abraham, and Bond 2012; Faulkner, Hannigan, and Fitzmaurice 2014). As female students are underrepresented in engineering courses (in this study, the average rate was 12%), it is generally difficult to separate the influence of gender on academic achievement in engineering (Ackerman, Kanfer, and Beier 2013).

Inconsistent observations were made regarding students' age, with respect to the length of the gap between secondary and tertiary education. Younger students, on average, showed higher first-year performance, and the risk to withdraw appeared to increase with age. Again, these results were moderated by cognitive variables, as traditional students usually are younger than students with a non-traditional background. There also were some heteroscedasticity issues as the majority of students were between 18 and 21 years old, whereas in the much smaller group of older students, the data set was very heterogeneous (ranging from 22 to 49 years of age). It can be drawn from our data that older students tend to withdraw more quickly if they are facing performance issues, but beyond this very weak trend, age appeared to be unrelated to study success.

Some effects were caused by the federal state in which secondary school was attended, suggesting that some of the changes to secondary education in Germany negatively influenced student performance (see also Knospe 2011; Greefrath, Koepf, and Neugebauer 2016). However, with a high interaction with other school-related preconditions, these effects are relatively weak and might as well be found irrelevant in the further course of the project.

Overall, up to 37% of the variance in Mathematics I and up to 36% of the variance in cumulated GPA could be accounted for by multiple linear regressions. Table 2 shows an overview of the different estimations and the variables that showed a significant contribution. Binary logistic regression with the dichotomous variable retention showed similar relations as the linear regression models, with varying power of secondary school GPA and pre-test results. Although the regression model was significant ($p < .01$) it also was too weak to predict drop-outs, suggesting that student withdrawal only to

**Table 2.** Regression analyses results: significant factors in relation to dependent variables Mathematics I (cohorts 2011–2014), cumulated GPA at the end of the degree programme, and retention (2011–2013).

| | Mathematics I | | | | Cum. GPA | | | Retention | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 11 | 12 | 13 | 14 | 11 | 12 | 13 | 11 | 12 | 13 |
| *n* | 383 | 524 | 482 | 465 | 368 | 522 | 479 | 377 | 533 | 496 |
| *Preconditions:* | | | | | | | | | | |
| Gender | | * | | | | | | | | |
| Age | | | | | | | | * | | |
| Gap school / university | | * | | | * | * | | * | * | * |
| Federal state | | | | * | * | | * | | | * |
| Type of school | | * | * | | * | * | * | | * | * |
| Mathematics grades at school | * | * | | | | | | | | |
| Secondary school GPA | * | * | * | * | * | * | * | | * | * |
| Diagnostic pre-test result (%) | * | * | * | * | * | | * | * | | |
| $R^2$ | .25 | .26 | .37 | .33 | .31 | .33 | .36 | .24 | .24 | .21 |

*$p < .01$.

some extent can be described by this data set and probably is affected by a more complex combination of factors (Robbins et al. 2004; Zhang et al. 2004).

These outcomes mirror the literature on academic achievement in engineering, with very stable relations between school performance, prior knowledge level, and success in MINT-related subjects (Budny, LeBold, and Bjedov 1998; Zhang et al. 2004; Kokkelenberg and Sinha 2010; Faulkner, Hannigan, and Fitzmaurice 2014; van Soom, Donche, and Costa 2014). It can be concluded from these analyses that poor values in any of the achievement-related variables, and particularly in secondary school GPA and diagnostic pre-test results, are a risk factor regarding tertiary achievement.

### 3.2. Pre-course learning gains

After having verified the importance of mathematics prior knowledge level for study success in the engineering programme, factors influencing learning gains in the pre-course were investigated. Analyses of variance were performed for each variable on pre-test results and gain score.

In 2014, the 603 students who participated in both tests achieved an average pre-test score of 49.7 (standard deviation = 16.0) and an average post-test score of 55.2 (stand. dev. = 17.5). By comparison, students who had not participated in the pre-test achieved a post-test mean score of 47.3 ($n = 105$; stand. dev. = 18.2). In both samples, variance was rather high, with results ranging from 7% to 98%. The gain score, as well, had a large variance with a maximum of plus 61.8 and a minimum (negative) gain score of −37.5. Thus, only 50% ($n = 302$) obtained a gain score of plus 5 or more, while 186 students had no gains (gain score between +5 and −5) and 115 students had a negative gain score (less than −5).

#### 3.2.1. Course type

Students who participated in an additional programme had below-average pre-test results (mean score = 45.3; $n = 204$) and an average post-test result of 50.9. In this group, pre–post-test difference was significantly affected by the type of course a student chose to attend. Face-to-face course participants, on average, had a gain score of 3.6 ($n = 91$), whereas students who completed the e-tutoring course had an average gain score of 6.7 ($n = 85$). The highest learning gains were achieved by students who had participated in both course types, e-tutoring and face-to-face, with an average gain score of 9.1 ($n = 28$, pre-test mean score = 44.2; post-test mean score = 53.3).

It can be seen from Table 3 that in the face-to-face group, pre-test results were even poorer than in the e-tutoring course. Looking at the demographic data, it also seemed that the face-to-face course had been preferred by non-traditional students. Although these between-group differences were not significant, it may be hypothesised that students' preconditions and preferences had an additional influence on the learning outcomes of the face-to-face group.

#### 3.2.2. Affective and metacognitive variables

It had been hypothesised that mathematics attitude items would correlate with each other, which they did, thus replicating existing results that suggest relations between mathematics liking and mathematics self-confidence (Parsons, Croft, and Harrison 2009). Significant relations with pre-test results were also found for nearly all attitude items, suggesting that a positive attitude towards mathematics is related to a higher level of prior knowledge. A critical point were the often skewed

**Table 3.** Pre- and post-test results 2014: complete data set in comparison to chosen pre-course type ($n = 603$).

| | Participants both tests | Self-study | Face-to-face | E-tutoring | Face-to-face + e-tutoring |
|---|---|---|---|---|---|
| $n$ | 603 | 386 | 91 | 85 | 28 |
| Pre-test (%) | 49.7 | 52.4 | 43.6 | 47.5 | 44.2 |
| Post-test (%) | 55.2 | 57.9 | 47.2 | 54.2 | 53.3 |
| gain score | 5.5 | 5.5 | 3.5 | 6.7 | 9.1 |

distributions: participants more often expressed positive attitudes towards mathematics, or felt reluctant to express negative attitudes, leading to small case numbers. For example, only 13% ($n = 77$) of first-year students were on the negative side of the statement 'I enjoy learning mathematics' (strongly disagree: $n = 15$; disagree: $n = 62$), whereas 63% agreed ($n = 277$) or strongly agreed ($n = 89$). An impact of these scales on gain score could not be observed; particularly in the group of at-risk students, a positive attitude was unrelated to learning outcomes. Two interpretations may be drawn from these results: First of all, engineering students in this study showed very positive attitudes towards mathematics, suggesting that they were well aware of the important role the subject plays in their chosen degree programme. In this context, it also can be hypothesised that students' answers were influenced by social desirability. Very high levels of mathematics liking and confidence, however, were mainly observed for students with a high level of prior knowledge, suggesting that attitudes are more strongly attached to students' preconditions than to their actual learning situation.

Non-normal distributions were also observed for the learning strategies scale. Four items addressing a proficient use of learning strategies were significantly related to each other, and to pre-test results, indicating that students able to manage their learning process had a higher level of prior knowledge in mathematics, as well. However, these relations were never linear, so that these variables only allowed to differentiate between (very good) students who 'strongly agreed' to an item like 'I usually managed to keep to my schedule' ($n = 43$; pre-test mean scores = 58.6) and the rest of the sample. Thus, the assumption that high levels in the learning strategies scales would be related to high learning gains could not be confirmed. Particularly in the at-risk group, these items were more or less unrelated to gains.

### *3.2.3. Effort*

Students' self-reports as well as LMS log files were analysed for the measurement of effort. In the evaluation questionnaire, students had answered how many learning modules they had worked through, how many hours per week they had studied, and how they estimated their overall engagement (Likert-scaled item 'I invested a lot of time into the study preparation'). Analysis of variance showed that students who scored high on these items also showed higher learning gains. The ANOVA, however, was not significant for these variables, with large within-group variation.

The page view count drawn from the LMS database, as well, failed to deliver significant results. Out of the existing 684 learning module pages, the average student visited 240 pages (the median was 121). Students with 0–10 page views showed poorer gains than the rest of the sample, but otherwise this variable did not significantly explain achievement in the pre-course. Similarly, the number of forum posts in the e-tutoring course was unrelated to learning gains. The e-tutoring groups were highly heterogeneous regarding communication preferences, and the case numbers were too small for statistical interpretation. Analysis of single cases, as well, did not suggest that a high (or low) number of forum posts were related to achievement.

Finally, the number of self-tests per student were analysed. Each learning module provided a final self-assessment, consisting of 10–15 randomised items (thus with each test attempt new items were presented and the number of attempts was unlimited). The highest number of test attempts was 83, but only a minority took more than 10 tests. Transformed to a five-step ordinal variable, with 'no test attempts', '1–5 attempts', '6–10 attempts', '11–20 attempts', and '21 and more attempts', this variable significantly differentiated between higher/lower achievement in the pre-course (see Table 4). Students with no test attempts had the poorest learning gains (gain score = 3.8), and students with 21 and more attempts had an average gain score of 12.0 ($p < .01$).

These results suggest that the number of test attempts is a reliable indicator of students' effort, at least in the domain of mathematics. Macfadyen and Dawson (2010) reported similar results for a biology course – and an even stronger impact of the total number of forum posts, an effect that could not be confirmed by this study. The results also support the view that study time or number of page views are less reliable indicators of student engagement in e-learning environments (Samson 2015).

**Table 4.** Pre- and post-test results 2014: complete data set in comparison to number of test attempts ($n = 603$).

| | Participants both tests | No test attempts | 1–5 attempts | 6–10 attempts | 11–20 attempts | ≥21 attempts |
|---|---|---|---|---|---|---|
| *n* | 603 | 296 | 167 | 55 | 60 | 25 |
| Pre-test (%) | 49.7 | 50.2 | 48.2 | 52.0 | 49.9 | 49.0 |
| Post-test (%) | 55.2 | 54.0 | 53.7 | 57.2 | 60.4 | 61.0 |
| Gain score | 5.5 | 3.8 | 5.6 | 5.3 | 10.5 | 12.0 |

### 3.3. Complete model: pre-course participation and study success

Assuming poor pre-test results being a risk factor, pre-course learning gains were expected to reduce this risk. Thus, the gain score was added to the basic model (as described in Section 3.1 and in Table 5, model 2). The gain score significantly contributed to explaining Mathematics I achievement (*B* coefficient gain score = .014; see Table 5, model 2). Compared to the dominant role of prior knowledge, this effect was not very strong; thus, a noticeable change in Mathematics I was only predicted for students with very high learning gains. For example, a student with a gain score of 20 was predicted an increase in Mathematics I grades by .28, compared to a similar student with a gain score of 0 (Note that test scores ranged from 0 to 100 and that Mathematics I grades ranged from 1 to 5).

Finally, variables related to pre-course participation were added to the multiple model. The two scales, students' attitudes towards the subject as well as use of learning strategies, had shown skewed or non-linear distributions and thus were excluded from the regression analysis.

The course type a student participated in was not significantly related to performance in Mathematics I. As mainly students with a relatively poor pre-test result participated in an additional course, the impact of this variable was apparently not strong enough to overpower the variables related to prior knowledge. Self-reported study time as well as page view count were unrelated to Mathematics I. In this model, only the number of pre-course test attempts showed a significant contribution (see Table 5, model 2). Even if the effect is relatively small, the results show that high levels of pre-course participation are still visible in the Mathematics I examination which is taken several months later. Table 5 gives a summary of the changes in variance explained ($R^2$) when gain score and effort (model 2) were added to the basic model 1.

As a final analysis, it was investigated if the group of students who had *not* participated in the pre-test or the pre-course programme ($n = 105$) differed in their Mathematics I results. The multiple model suggested significantly poorer first-year performance for non-participants, leading to a difference of −.5 in Mathematics I grades ($p < .01$). Similar effects could be observed for the previous cohorts (2011–2014; see Table 6). Accordingly, it could be observed that students who had not participated in the pre-course more often failed this exam (note that in this data set, 'failure' means grades above

**Table 5.** Summary of hierarchical regression analysis for variables predicting Mathematics I ($n = 465$).

| | Model 1 | | | Model 2 | | |
|---|---|---|---|---|---|---|
| | *B* | *SE B* | β | *B* | *SE B* | β |
| Gender | .14 | .12 | .05 | .08 | .12 | .03 |
| Age | .03 | .05 | .06 | .04 | .04 | .07 |
| Gap school/university | −.04 | .06 | −.04 | −.07 | .06 | −.09 |
| Federal state[a] | .47 | .15 | .14** | .32 | .15 | .10* |
| Type of school | .19 | .16 | .09 | .15 | .15 | .07 |
| Mathematics grades | .00 | .15 | .00 | −.07 | .14 | −.03 |
| Secondary school GPA | .44 | .10 | .23** | .43 | .10 | .23** |
| Diagnostic pre-test result (%) | .03 | .00 | .40** | .03 | .00 | .43** |
| Gain Score | | | | .01 | .00 | .14** |
| Number of test attempts | | | | .02 | .01 | .11* |
| $R^2$ | | .33 | | | .36 | |

Note: Model 1: students' preconditions when entering university; Model 2: gain score and number of test attempts added.
*B*: unstandardised regression coefficient; *SE* B: standard error; β: standardised regression coefficient; significance levels
[a]Federal state Baden-Wuerttemberg = baseline.
$^*p < .05$; $^{**}p < .01$.

**Table 6.** Mathematics 1 results 2011–2014, pre-course participants vs. non-participants.

| | Mathematics I failure rate | | | | Mathematics I grades[a] | | | |
|---|---|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 | 2011 | 2012 | 2013 | 2014 |
| Non-participation | 5.1 | 8.7 | 10.2 | 11.7 | 2.8 | 3.1 | 3.0 | 3.3 |
| Participation | 2.5 | 2.6 | 4.8 | 3.0 | 2.6 | 2.6 | 2.8 | 2.8 |
| Total | 3.2 | 3.8 | 5.6 | 4.1 | 2.7 | 2.7 | 2.8 | 2.8 |

[a]Average grades, measured on a linear scale from 1 (=A) to 5, an exam graded >4.0 is failed.

4.0 after one resit and one oral examination). There was an overall increase in Mathematics I failures from 2011 to 2014, which particularly showed in the group of non-participants.

The effectiveness of the pre-course thus could be established, considering the above-mentioned limitations. Descriptive analyses suggested that the rate of at-risk students in the post-test-only group was slightly higher, with more students having attended vocational schools and a higher rate of medium to poor school grades. These differences were not significant, with a high variance and a considerable number of very high performing students. However, it may be hypothesised that students who take the diagnostic pre-test and participate in the pre-course already show a higher interest in their degree programme, which might result in better first-year performance.

## 4. Discussion

Major assumptions regarding relations between prior achievement, domain-related prior knowledge, and study success in engineering could be reproduced in this study (Zhang et al. 2004; Hell, Linsner, and Kurz 2008; Ackerman, Kanfer, and Beier 2013; Hall et al. 2015). In a multiple model secondary school, GPA and results in the mathematics pre-test were found to be the strongest predictors of first- and final-year achievement. The type of secondary school was also found to be a significant factor, putting students from vocational schools and students with non-traditional backgrounds at a disadvantage. Other variables, like gender, age, or German federal state, were repeatedly found to interact with school-related and cognitive variables. After controlling for these interferences, demographic variables were no longer significantly related to study success.

After having confirmed the assumption that gaps in basic mathematics knowledge significantly affect students' chances to succeed, it was investigated if pre-course participation would improve these chances. The analyses revealed significantly higher first-year performance in mathematics for students who participated in the pre-course than for students who did not. Over a period of four years, this accounted for up to .5 grades in the Mathematics I exam. Given the lack of randomisation and an overall high variance, these outcomes should not be overrated; pre-course participation not necessarily led to good first-year performance. However, *non*-participation certainly added to the risk of students with poor prior knowledge.

Some of the results in this study demand further analyses, for example the considerable number of students who obtained only small or even negative gain scores. Many students probably did not study a lot, as suggested by the log file analyses. Others, however, were unable to benefit from pre-course participation in spite of their learning activities. It is hypothesised that some students' knowledge gaps were too broad or too fundamental to be adequately addressed by a relatively short and compact pre-course. At the moment, we are analysing a follow-up interview study that explores the student perspective more deeply.

Further research may also be needed to better understand the questionnaire answer patterns. The attitude scales, for example, showed that prior achievement correlated with students' attitude towards mathematics: students with a high level of prior knowledge more often expressed very positive attitudes towards learning mathematics. In the group of poor performing students, however, the results were less consistent. While the majority of students' expressed a positive view, their learning gains were unrelated to their attitudes towards the subject. The scales thus failed to differentiate between successful and less successful pre-course participation of the at-risk group.

Relatively strong learning gains (post–pre-test difference) were observed for students who had attended an additional e-tutoring programme. This group outperformed face-to-face participants, an effect to some extent caused by differences in course duration and concept. It also was not possible to eliminate the bias caused by self-enrolment. However, it could be observed that the majority of face-to-face students did not engage in online learning activities. These observations are interesting in the light of the analyses of pre-course learner behaviour. The only non-moderated and significant factor regarding learning gains was the number of online test attempts. This variable not only correlated with pre-course learning gains but showed a visible effect on first-year performance in mathematics, as well. Positive, but non-significant influence on learning gains were found for study time, number of learning modules, or self-perceived effort, whereas the number of page visits in the e-learning environment was completely unrelated to learning gains. There remain open questions regarding the low impact of items addressing the use of learning strategies. Ledermüller and Fallmann (2017), as well, were unable to find a mediating effect of learning strategies scales on achievement. In their study on learner behaviour of accounting and management students, only prior knowledge and number of online self-tests significantly affected the exam score at the end of the course. In that context, it has been discussed if self-reports are an adequate approach to measuring learning strategy use (Winne and Jamieson-Noel 2002; Greene and Azevedo 2010). High performing students may find it easier to answer metacognitive items (Case 2004), and they also are more likely to answer them consistently (Thiessen and Blasius 2008). Alternative approaches have been suggested, for example using e-portfolios for more comprehensive monitoring of learning activities. But working with such tools demands time, effort, and conscientiousness and can be considered a metacognitive strategy in itself (Zimmerman et al. 2011). Future research will show if more advanced learning analytics tools provide more consistent observations of learner behaviour (Gibson and Ifenthaler 2017). Such technical solutions might also solve issues of non-response or social desirability. In this study, it could only be hypothesised why students did not answer the evaluation, a question that will have to be addressed in further qualitative analyses.

Concluding, what implications for the design of pre-courses in mathematics can be made based on this study? First, it could be shown that entering students' mathematical skills indeed are heterogeneous in many ways. The average pre-test results of non-traditional students, for example, were significantly poorer than those of traditional students, but in both groups there was a very large variance. Knowledge gaps could be observed in all ten mathematical areas, and our results did not indicate that some were more relevant for study success in engineering than others. It is suggested that either 'basic knowledge in mathematics' is a more general concept that cannot be narrowed down to certain topics – or that our instruments lacked the accuracy to clearly differentiate between the ten knowledge areas.

Second, formative self-assessment could be identified as an effective learning strategy in the context of knowledge re-activation, basic skill training and consolidation. Engaging in self-tests not only was positively related to learning gains, the evaluation also revealed that students highly appreciated opportunities to practice and self-monitor their learning. The role of engagement and of practice in the self-study process will be investigated more deeply in the further course of the project. It is hypothesised that the willingness to take self-tests is a good indicator of students' overall engagement (Gibbs and Simpson 2004; Pachman, Sweller, and Kalyuga 2013). However, our analyses also reveal that a considerable number of students did not make use of the provided tools.

Therefore, as a third aspect, more needs to be done to engage students in formative self-assessment. Previous research has shown that inexperienced students tend to procrastinate and thus benefit from guided and structured course designs (Artino and Stephens 2009). It seems plausible that the more binding character of the e-tutored course in this study had a positive effect on the at-risk group, therefore similar course structures should be applied to the face-to-face sessions.

Finally, the potential of predictive models for engineering education in the transition phase is discussed. Correlations between prior knowledge, prior performance, and subsequent performance are well-documented (Hattie 2009); the reproduction of such relations helped to establish external validity in this study. At the same time, a lot of information was missing. With more than 60% of variance unaccounted for, many students in this study showed a good Mathematics I performance in spite of a poor pre-test result and there also remained a number of students who performed reasonably well in the pre-test yet failed their first exam. It is therefore not recommended to 'predict' study success (or failure) of an individual student. We do however suggest informing pre-course participants of the outcomes of such studies. In an abridged version, elements of this report were made available for tutors and students (see www.optes.de) and can be used to discuss test scores with students and thus raise awareness for the role of basic knowledge in mathematics.

## Acknowledgements

Responsibility for the content published in this article, including any opinions expressed therein, rests exclusively with the authors. Test items and learning material are licenced under the creative commons attribution 3.0 unported and can be provided via www.optes.de.

## Disclosure statement

No potential conflict of interest was reported by the authors.

## Funding

Support for this publication was provided by the German Federal Ministry of Education and Research (BMBF) in the context of the Federal 'Quality pact for teaching' (ref. number 01PL17012A).

## Notes on contributors

***Katja Derr*** worked in the field of e-learning design and development before completing a degree in education at Freiburg University of Education. Since 2007, she has been involved in mathematics e-learning projects in tertiary education, since 2012 she is a research staff member in the joint project optes.

***Reinhold Hübl*** received his PhD in mathematics from the University of Regensburg in 1987. After working in mathematical research and software development for several years, he joined the staff of DHBW Mannheim in 2009 where he teaches mathematics and acts as scientific coordinator of the centre of basic knowledge in mathematics and sciences.

***Mohammed Zaki Ahmed*** received his PhD in electrical engineering from Plymouth University in 2003. He works in signal processing research and manages the MEng and BEng programmes in Electrical and Electronic Engineering at Plymouth University.

## References

Ackerman, Phillip L., Ruth Kanfer, and Margaret E. Beier. 2013. "Trait Complex, Cognitive Ability, and Domain Knowledge Predictors of Baccalaureate Success, STEM Persistence and Gender Differences." *Journal of Educational Psychology* 105 (3): 911–927.

Artino, Anthony R., and Jason M. Stephens. 2009. "Academic Motivation and Self-Regulation: A Comparative Analysis of Undergraduate and Graduate Students Learning Online." *The Internet and Higher Education* 12: 146–151.

Ashby, Jean, William A. Sadera, and Scot W. Mcnary. 2011. "Comparing Student Success Between Developmental Math Courses Offered Online, Blended, and Face-to-Face." *Journal of Interactive Online Learning* 10 (3): 128–140.

Bargel, Tino. 2015. *Studieneingangsphase und heterogene Studentenschaft - neue Angebote und ihr Nutzen: Befunde des 12. Studierendensurveys an Universitäten und Fachhochschulen*. Hefte zur Bildungs- und Hochschulforschung 83. Konstanz: AG Hochschulforschung University of Konstanz.

Besterfield-Sacre, Mary, Cynthia J. Atman, and Larry J. Shuman. 1997. "Characteristics of Freshman Engineering Students: Models for Determining Student Attrition in Engineering." *Journal of Engineering Education* 86 (2): 139–149.

Budny, Dan, William LeBold, and Goranka Bjedov. 1998. "Assessment of the Impact of Freshman Engineering Courses." *Journal of Engineering Education* 87 (4): 405–411.

Case, Jennifer. 2004. "Approaches to Learning: A Critical Examination of Inventory Responses from Third Year Chemical Engineering Students." Proceedings of the 12th Annual Conference of the Southern African Association for Research in Mathematics, Science and Technology Education SAARMSTE, Cape Town, 102–110.

Cook, Colleen, Fred Heath, and Russel L. Thompson. 2000. "A Meta-Analysis of Response Rates in Web- or Internet-Based Surveys." *Educational and Psychological Measurement* 60 (6): 821–836.

COSH cooperation schule:hochschule. 2014. "Mindestanforderungskatalog Mathematik (2.0) der Hochschulen Baden-Württembergs für ein Studium von WiMINT-Fächern.". Accessed May 26, 2017. http://www.mathematik-schule-hochschule.de/images/Aktuelles/pdf/MAKatalog_2_0.pdf.

Crowther, K., D. Thompson, and C. Cullingford. 1997. "Engineering Degree Students Are Deficient in Mathematical Expertise – Why?" *International Journal of Mathematical Education in Science and Technology* 28 (6): 785–792.

Derr, Katja, Reinhold Hübl, and Mohammed Z. Ahmed. 2015. "Using Test Data for Successive Refinement of an Online Pre-Course in Mathematics." Proceedings of the 14th European Conference on e-Learning ECEL, Hatfield, 173–180.

Ehrenberg, Ronald G. 2010. "Analyzing the Factors That Influence Persistence Rates in STEM Field, Majors: Introduction to the Symposium." *Economics of Education Review* 29: 888–891.

Eley, Malcolm G., and J. H. F. Meyer. 2004. "Modelling the Influences on Learning Outcomes of Study Processes in University Mathematics." *Higher Education* 47 (4): 437–454.

Engineering Council. 2000. *Measuring the Mathematics Problem*. Joint Report, London. Accessed March 16, 2018. http://www.engc.org.uk/EngCDocuments/Internet/Website/Measuring%20the%20Mathematic%20Problems.pdf.

Fan, Weimiao, and Zheng Yan. 2010. "Factors Affecting Response Rates of the Web Survey: A Systematic Review." *Computers in Human Behavior* 26: 132–139.

Faulkner, Fiona, Ailish Hannigan, and Olivia Fitzmaurice. 2014. "The Role of Prior Mathematical Experience in Predicting Mathematics Performance in Higher Education." *International Journal of Mathematical Education in Science and Technology* 45 (5): 648–667.

Faulkner, Fiona, Ailish Hannigan, and Olivia Gill. 2010. "Trends in the Mathematical Competency of University Entrants in Ireland by Leaving Certificate Mathematics Grade." *Teaching Mathematics and Its Applications* 29 (2): 76–93.

Federal Statistical Office (Statistisches Bundesamt). 2016. *Hochschulen auf einen Blick*. destatis. Wiesbaden. Accessed March 1, 2017. www.destatis.de/EN.html.

Gibbs, Graham, and Claire Simpson. 2004. "Conditions Under Which Assessment Supports Student Learning." *Learning and Teaching in Higher Education* 1 (1): 3–31.

Gibson, David C., and Dirk Ifenthaler. 2017. "Preparing the Next Generation of Education Researchers for Big Data in Higher Education." In *Big Data and Learning Analytics in Higher Education: Current Theory and Practice*, edited by Ben K. Daniel, 29–42. Basel: Springer.

Greefrath, Gilbert, Wolfram Koepf, and Christoph Neugebauer. 2016. "Is There a Link Between Preparatory Course Attendance and Academic Success? A Case Study of Degree Programmes in Electrical Engineering and Computer Science." *International Journal of Research in Undergraduate Mathematics Education* 3: 143–167.

Greene, Jeffrey A., and Roger Azevedo. 2010. "The Measurement of Learners' Self-Regulated Cognitive and Metacognitive Processes While Using Computer-Based Learning Environments." *Educational Psychologist,* 45 (4): 203–209.

Hailikari, Telle, Anne Nevgi, and Erkki Komulainen. 2008. "Academic Self-Beliefs and Prior Knowledge as Predictors of Student Achievement in Mathematics: A Structural Model." *Educational Psychology* 28 (1): 59–71.

Hall, Cathy W., Paul J. Kauffmann, Karl L. Wuensch, William E. Swart, Karen A. DeUrquidi, O. H. Griffin, and C. S. Duncan. 2015. "Aptitude and Personality Traits in Retention of Engineering Students." *Journal of Engineering Education* 104 (2): 167–188.

Harackiewicz, Judith M., Kenneth E. Barron, John M. Tauer, and Andrew J. Elliot. 2002. "Predicting Success in College: A Longitudinal Study of Achievement Goals and Ability Measures as Predictors of Interest and Performance from Freshman Year Through Graduation." *Journal of Educational Psychology* 94 (3): 562–575.

Hattie, John. 2009. *Visible Learning. A Synthesis of Over 800 Meta-Analyses Relating to Achievement*. London: Routledge.

HEFCE. 2013. "Non-Continuation Rates at English HEIs. Trends for entrants 2005-06 to 2010-11." Accessed May 12, 2017. http://www.hefce.ac.uk/pubs/year/2013/201307.

Hell, Benedikt, Manuela Linsner, and Günther Kurz. 2008. "Prognose des Studienerfolgs." In *Studieneignung und Studierendenauswahl - Untersuchungen und Erfahrungsberichte*, edited by Michael Rentschler, and Hans P. Voss, 132–177. Aachen: Shaker.

Heublein, Ulrich, and Andrä Wolter. 2011. "Studienabbruch in Deutschland. Definitionen, Häufigkeit, Ursachen, Maßnahmen." *Zeitschrift für Pädagogik* 57 (2): 214–236.

Howson, A. G., A. D. Barnard, D. G. Crighton, N. Davies, A. D. Gardiner, J. M. Jagger, D. Morris, J. C. Robson, and N. C. Steele. 1995. "Tackling the Mathematics Problem." Joint Report by London Mathematical Society, Institute of Mathematics and Its Applications, Royal Statistical Society. Accessed June 8, 2017. http://www.mei.org.uk/files/pdf/Tackling_the_Mathematics_Problem.pdf.

Huang, Shaobo, and Ning Fang. 2013. "Predicting Student Academic Performance in an Engineering Dynamics Course: A Comparison of Four Types of Predictive Mathematical Models." *Computers & Education* 61: 133–145.

Johnson, Marianne, and Eric Kuennen. 2006. "Basic Math Skills and Performance in an Introductory Statistics Course." *Journal of Statistics Education* 14 (2). http://ww2.amstat.org/publications/jse/contents_2006.html.

Kadijevich, Djordje. 2006. “Developing Trustworthy TIMSS Background Measures: A Case Study on Mathematics Attitude.” *The Teaching of Mathematics* 9 (2): 41–51.

Knospe, Heiko. 2011. “Der Eingangstest Mathematik an Fachhochschulen in Nordrhein-Westfalen von 2002 bis 2010.” Proceedings 9. Workshop Mathematik für ingenieurwissenschaftliche Studiengänge. *Wismarer Frege-Reihe* (2): 8–13.

Kokkelenberg, Edward, and Esha Sinha. 2010. “Who Succeeds in STEM Studies? An Analysis of Binghamton University Undergraduate Students.” *Economics of Education Review* 29: 935–946.

Kuncel, Nathan R., and Sarah A. Hezlett. 2007. “Standardized Tests Predict Graduate Students’ Success.” *Science Education* 315 (5815): 1080–1081.

Lawson, Duncan. 2000. “Changes in the Competency of A Level Students.” In *Measuring the Mathematics Problem*, 6–9. London: The Engineering Council.

Ledermüller, Karl, and Irmgard Fallmann. 2017. “Predicting Learning Success in Online Learning Environments: Self-Regulated Learning, Prior Knowledge and Repetition.” *Zeitschrift für Hochschulentwicklung* 12 (1): 79–99.

Macfadyen, Leah P., and Shane Dawson. 2010. “Mining LMS Data to Develop an ‘Early Warning System’ for Educators: A Proof of Concept.” *Computers & Education* 54 (2): 588–599.

Marbouti, Farshid, Heidi A. Diefes-Dux, and Johannes Strobel. 2015. “Building Course-Specific Regression-Based Models to Identify At-Risk Students.” Proceedings of the American Society for Engineering Educators Annual Conference, Seattle,ID 11229.

Meyer, J. H. F., and Malcolm G. Eley. 1999. “The Development of Affective Subscales to Reflect Variation in Students’ Experiences of Studying Mathematics in Higher Education.” *Higher Education* 37: 197–216.

Mullis, Ina V. S., Michael O. Martin, Pierre Foy, and Alka Arora. 2012. “TIMSS 2011 International Results in Mathematics.” TIMSS & PIRLS International Study Center.

Pachman, Mariya, John Sweller, and Slava Kalyuga. 2013. “Levels of Knowledge and Deliberate Practice.” *Journal of Experimental Psychology: Applied* 19 (2): 108–119.

Pant, Hans A., Petra Stanat, Ulrich Schroeders, Alexander Roppelt, Thilo Siegle, and Claudia Pöhlmann, eds. 2013. *IQB-Ländervergleich 2012. Mathematische und naturwissenschaftliche Kompetenzen am Ende der Sekundarstufe I*. Münster: Waxmann.

Pappano, Laura. 2012. “The Year of the MOOC.” *The New York Times, Education Life Supplement* (Nov 4): 26.

Parsons, Sarah J., Tony Croft, and Martin Harrison. 2009. “Does Students’ Confidence in Their Ability in Mathematics Matter?” *Teaching Mathematics and Its Applications* 28 (2): 52–68.

Pintrich, Paul R., and Elisabeth V. de Groot. 1990. “Motivational and Self-Regulated Learning Components of Classroom Academic Performance.” *Journal of Educational Psychology* 82 (1): 33–40.

Pintrich, Paul R., David A. F. Smith, Teresa Garcia, and Wilbert J. McKeachie. 1991. *A Manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ)*. Ann Arbor, MI: National Centre for Research to Improve Postsecondary Teaching and Learning.

Polaczek, Christa, and Gudrun Henn. 2008. “Vergleichende Auswertung des Mathematik-Eingangstests.” University of Applied Sciences Aachen.

Rach, Stefanie, and Aiso Heinze. 2017. “The Transition from School to University in Mathematics: Which Influence Do School-Related Variables Have?” *International Journal of Science and Mathematics Education* 15 (7): 1343–1363.

Richardson, Michelle, Charles Abraham, and Rod Bond. 2012. “Psychological Correlates of University Students’ Academic Performance: A Systematic Review and Meta-Analysis.” *Psychological Bulletin* 138 (2): 353–387.

Robbins, Steven B., Kristy Lauver, Huy Le, Daniel Davis, Ronelle Langley, and Aaron Carlstrom. 2004. “Do Psychosocial and Study Skill Factors Predict College Outcomes? A Meta-Analysis.” *Psychological Bulletin* 130 (2): 261–288.

Samson, Perry J. 2015. “Can Student Engagement be Measured? and, if so, Does it Matter?” Frontiers in Education Conference FIE.

Schiefele, Ulrich, and Klaus Peter Wild. 1994. “Lernstrategien im Studium: Ergebnisse zur Faktorenstruktur und Reliabilität eines neuen Fragebogens.” *Zeitschrift für Differentielle und Diagnostische Psychologie* 15 (4): 185–200.

Sclater, Niall, Alice Peasgood, and Joel Mullan. 2016. “Learning Analytics in Higher Education: A review of UK and international practice.” Bristol, MA: JISC Joint Information Systems Committee.

SEFI Mathematics Working Group. 2013. “A Framework for Mathematics Curricula in Engineering Education.” Brussels: European Society for Engineering Education.

Smith, Glenn G., and David Ferguson. 2005. “Student Attrition in Mathematics e-Learning.” *Australasian Journal of Educational Technology* 21 (3): 323–334.

Söderlind, Johan, and Lars Geschwind. 2017. “More Students of Better Quality? Effects of a Mathematics and Physics Aptitude Test on Student Performance.” *European Journal of Engineering Education* 42: 445–457.

Street, Hannah. 2010. “Factors Influencing a Learner’s Decision to Drop-Out or Persist in Higher Education Distance Learning.” *Online Journal of Distance Learning Administration* 13 (4). https://www.westga.edu/~distance/ojdla/winter134/street134.html.

Thiessen, Victor, and Jörg Blasius. 2008. “Mathematics Achievement and Mathematics Learning Strategies: Cognitive Competencies and Construct Differentiation.” *International Journal of Educational Research,* 47 (6): 362–371.

Trapmann, Sabrina, Benedikt Hell, Sonja Weigand, and Heinz Schuler. 2007. “Die Validität von Schulnoten zur Vorhersage des Studienerfolgs – eine Metaanalyse.” *Zeitschrift für Pädagogische Psychologie* 21 (1): 11–27.

van Soom, Carolien, Vincent Donche, and Costa Manuel João. 2014. "Profiling First-Year Students in STEM Programs Based on Autonomous Motivation and Academic Self-Concept and Relationship with Academic Achievement." *PLoS One* 9 (11): e112489.

Winne, Philip H., and Dianne Jamieson-Noel. 2002. "Exploring Students' Calibration of Self Reports About Study Tactics and Achievement." *Contemporary Educational Psychology*, 27: 551–572.

Xie, Yu, and Kimberlee A. Shauman. 2005. *Women in Science. Career Processes and Outcomes*. Cambridge, MA: Harvard University Press.

Zhang, Guili, Timothy J. Anderson, Matthew W. Ohland, and Brian R. Thorndyke. 2004. "Identifying Factors Influencing Engineering Student Graduation: A Longitudinal and Crossinstitutional Study." *Journal of Engineering Education* 93: 313–320.

Zimmerman, Barry J., Adam Moylan, John Hudesman, Niesha White, and Bert Flugman. 2011. "Enhancing Self-Reflection and Mathematics Achievement of At-Risk Urban Technical College Students." *Psychological Test and Assessment Modeling* 53 (1): 141–160.

A.2 Derr, K. (2017). Identifying Consistent Variables in a Heterogeneous Data Set: Evaluation of a Web-Based Pre-Course in Mathematics. Electronic Journal of e-Learning EJEL 15 (1), pp. 82–93.

ERIC Number: EJ1140127

files.eric.ed.gov/fulltext/EJ1140127.pdf
http://www.ejel.org/volume15/issue1

# Identifying Consistent Variables in a Heterogeneous Data Set: Evaluation of a Web-Based Pre-Course in Mathematics

**Katja Derr**
**Baden-Wuerttemberg Cooperative State University Mannheim, Germany**
katja.derr@dhbw-mannheim.de

**Abstract:** E-learning has made course evaluation easier in many ways, as a multitude of learner data can be collected and related to student performance. At the same time, open learning environments can be a difficult field for evaluation, with a large variance in participants' knowledge level, learner behaviour, and commitment. In this study the effectiveness of a mathematics pre-course administered to four cohorts of prospective students at a technical faculty in Germany was evaluated. Deficits in basic mathematics knowledge are considered one risk factor regarding graduation in STEM-related subjects, thus the overall goal was to investigate if the pre-course enabled "at risk" students to improve their starting position. A data analysis was performed, relating students' preconditions when entering university, their attitude towards mathematics, and their use of learning strategies with further study success. The strongest determinant of first year performance were results in a diagnostic pretest, confirming both the importance of basic mathematics knowledge for academic achievement in engineering and the reliability of the chosen pre-posttest design. Other outcomes were quite unexpected and demanded deeper analyses. Students who had participated in additional face-to-face courses, for example, showed less learning gains than students who had participated in an e-tutoring version. It also could be observed that meta-cognitive variables failed to explain successful course participation. Reasons for these outcomes are discussed, suggesting reliability threats and interactions between students' preconditions and their learner behaviour. A significant and unmoderated impact on students' learning gains in the pre-course was found for the number of online test attempts, making this variable a reliable indicator of student engagement. The evaluations show that open learning designs with heterogeneous learner groups can deliver meaningful information, provided that limitations are considered and that external references, like academic grades, are available in order to establish consistency.

**Keywords:** learning analytics, pre-course, mathematics, formative e-assessment, STEM

## 1. Introduction

The educational backgrounds of students entering university are increasingly diverse, leading to a growing demand for preparatory and bridging courses – not only, but particularly in mathematics (Parker, 2005; Croft, *et al.*, 2009; Faulkner, *et al.*, 2014). A growing number of undergraduates lack basic mathematical skills and are not adequately prepared for the demands of a STEM (Science, Technology, Engineering, Mathematics) degree programme, an issue addressed since the 1990ies as the "mathematics problem" (Howson, *et al.*, 1995). Different reasons for the mathematics problem have been suggested, from abridged school curricula (Lawson, 2000) to a general increase in transfers to tertiary education (HEFCE, 2013) to a higher rate of students from non-traditional backgrounds (Faulkner, *et al.*, 2014). Today, nearly all technical faculties in Germany provide pre-courses in mathematics.

When addressing diverse groups of learners the implementation of web-based content may be beneficial; students are free to pace their learning and the course can be accessed by participants who not (yet) live near the campus. With many learner data stored online, the evaluation of these courses has become much easier, and learning analytics seem to offer countless possibilities for statistical analyses. But not all collected data may deliver meaningful results. In distance education, drop-out rates tend to be higher (Ashby, *et al.*, 2011), particularly in open access courses (Pappano, 2012) while answer rates are often lower (Cook, *et al.*, 2000; Fan and Yan, 2010). Web-based university pre-courses thus can be a difficult field for evaluation: access is free for all prospective students but only a section of each cohort participates. In this group, commitment can be very diverse and students often withdraw without giving feedback (Smith and Ferguson, 2005; Street, 2010; Gasiewski, *et al.*, 2012). Technical barriers and data privacy policies may also prohibit a connection between pre-university performance and further academic achievement.



Reference this paper as: Derr K, "Identifying Consistent Variables in a Heterogeneous Data Set: Evaluation of a Web-Based Pre-Course in Mathematics" *The Electronic Journal of e-Learning Volume 15 Issue 1 2017*, (pp82-93) available online at www.ejel.org



In this article different aspects of the evaluation of a web-based pre-course in mathematics are reported, with a special focus on the reliability and consistency of the collected data. The pre-course was not mandatory but students were encouraged to take the initial diagnostic self-test in order to identify knowledge gaps. These test results were also considered one important factor in the overall data model. The diagnostic feedback advised students to close existing gaps via self-study or by participating in additional face-to-face or e-tutoring courses. Reliability issues had to be considered regarding the open design and the resulting non-randomized groups of learners. It also had to be considered that some students did not participate at all; it was interesting to compare this group's academic achievement with the "experimental" group but, again, students' preconditions and interactions with other variables had to be taken into account.

In order to differentiate between successful and less successful pre-course participation a pre-posttest design was administered and had to be evaluated regarding its consistency. Finally, the informative value of different sets of metacognitive variables, from attitudes towards the subject to the use of learning strategies to measures of student engagement, was investigated regarding their consistency, their reliability, and their potential to predict learning gains in the pre-course. Analyses were based on data collected from four cohorts (2011-2014) enrolled at Baden-Wuerttemberg Cooperative State University Mannheim. Anonymised examination results from the first and final year of the degree programme were added as dependent variable in a multiple regression model. A significant relation to this measure of academic achievement also served as an indicator for each independent variable's reliability.

### 1.1 Approach

In the academic field, there has been a growing interest in "educational data mining" (Romero and Ventura, 2010). Based on predictive models, students at risk to fail a course can be identified at an early stage and interventions suggested (Campbell and Oblinger, 2007; Corrigan, *et al.*, 2015). Prior achievement, for example, measured by secondary school GPA (grade point average), has been found a valid predictor of tertiary GPA and of student retention. Students with a high level of domain-related prior knowledge will have it easier to acquire new knowledge, thus in technical degree programmes mathematics grades or mathematics placement test scores have repeatedly been found of particular importance for later study success (Budny, *et al.*, 1998; Zhang, *et al.*, 2004; Warwick, 2007; Ehrenberg, 2010; Faulkner, *et al.*, 2010; Kokkelenberg and Sinha, 2010).

A first approach to evaluate the effectiveness of the mathematics pre-course programme therefore was to confirm these relations with the collected data. It was hypothesized that students with good secondary school grades and a high level of prior knowledge in mathematics would show a higher level of academic achievement in engineering. In this basic model the impact of personal and demographic variables (age, gender, federal state) was analysed, as well, with the overall goal to identify students "at risk" to perform poorly, or to withdraw from the degree programme.

In a second step students' learning gains in the pre-course were to be measured. Thus a pre- and a posttest in mathematics was developed and administered to pre-course participants. Both tests were designed to be equally difficult, but consisted of different items as suggested for single group pre-posttest designs (Kane, 2013). The gain score, or difference between posttest and pretest results, thus could be interpreted as a measure of change in relation to a student's pretest result. It was expected that participation in the pre-course would positively affect gain scores of students who had showed poor pretest performance.

It then was investigated which factors most contributed to this gain score, with a focus on the "at risk" group. The impact of different pre-course elements and their combinations – self-study, e-tutoring, face-to-face – was one major interest. Considering the role of affective and metacognitive variables in the learning process, the influence of scales addressing these variables on learning gains of the "at risk" group was analysed, as well (Robbins, *et al.*, 2004; Richardson, *et al.*, 2012). For STEM subjects, Ackerman, *et al.* (2013) suggested a multiple regression model including cognitive and meta-cognitive variables. The authors reported a strong influence of mathematics placement tests (isolated $R^2$ = .21), but they also stressed the importance of students' self-concepts in mathematics (their self-confidence and attitudes towards the subject) and their ability to master and organize learning. It therefore was expected that positive attitudes towards the subject as well as an efficient use of learning strategies and a high level of student engagement would be correlated with learning gains. Finally, the impact of the collected pre-course variables on first year achievement was to be evaluated in order to confirm, or disprove, the effectiveness of the pre-course design.

## 2. Data collection and tool development

Data from five engineering courses (mechanical engineering, mechatronics, computer science, electrical engineering, and industrial engineering) were analysed and evaluated. In a multiphase research design (Creswell and Plano Clark, 2011; Richey and Klein, 2005) repeated evaluations of test results, group interviews, questionnaire data and statistical information were used to revise and successively improve the programme. Throughout the study the learning management system (Open Source LMS Moodle) was used to administer, evaluate, and optimize the different quantitative tools. The finally enacted modular design consisted of an e-learning environment covering the secondary school curriculum in mathematics, initiated and completed by a pre- and a posttest, plus supplementary face-to-face and e-tutoring courses. The first two pre-course evaluations had shown that students' learning preferences were quite diverse. While many students wanted to learn independently (and alone), others claimed to need additional support and missed face-to-face interaction. Considering the differences in participants' starting positions and their personal situation in the phase between school and university it was decided to modularize the programme, with different learning scenarios open for self-selection (Jackson and Johnson, 2013). Students now could sign up for weeklong on-campus courses or for an e-tutoring programme that lasted one month. All students had access to the same web-based learning material, but in the e-tutoring course the learning process was structured and monitored by mathematics lecturers. Every week students uploaded a completed exercise sheet and were encouraged to discuss mathematical problems with peers and e-tutors.

### 2.1 Educational background

From the university's administration students' secondary school GPA (leaving certificate) was collected. Other school related variables, like gap between secondary and tertiary education, type of secondary school, or the area / federal state where school was attended were collected from a web-based questionnaire.

### 2.2 Prior knowledge level in mathematics (pre-posttest design)

Domain related prior knowledge was measured by a diagnostic test. As placement tests in mathematics are not mandatory at German universities, no standardized items were available for the development of the pre-posttest design. Two item sets were developed, covering the secondary school syllabus and structured alongside the ten e-learning modules, and underwent a two-year revision process. The first cohort's test results served as a database for classical and probabilistic item analyses. An Item Response Theory (IRT) approach was chosen to model each item's difficulty level and identify extreme outliers (Hambleton and Swaminathan, 2010). In combination with traditional measures, like mean scores and discrimination index, the Rasch model estimates delivered information on each item's quality and contribution to the test. Items that did not fit the model were revised or replaced, and the analysis was repeated in the following year. After two revisions both tests delivered consistent results (Cronbach's α pretest = .91 and posttest = .85) and no more outlying items; since 2013 the pre-posttest design has remained unchanged. Pre-posttest similarity was established by comparing pretest results with posttest results of a control-group that had neither participated in the pretest nor in the pre-course. With a consistent pre-posttest design, learning gains in the pre-course could be measured by pre-posttest difference.

### 2.3 Affective and meta-cognitive aspects of learning

Two Likert scales were administered, one addressing students' attitudes towards mathematics and mathematics learning, and another referring to their use of learning strategies. For the mathematics attitude scale an item set developed for the "Trends in International Mathematics and Science Study TIMSS" was employed (Kadijevich, 2006; Mullis*, et al.*, 2012). In this inventory, students' liking of the subject (for example "I am interested in mathematics") and their self-confidence in learning mathematics are addressed (for example "I learn things quickly in mathematics"). For the learning strategies scale subscales of the LIST inventory were used (Schiefele and Wild, 1994), a German adaptation of the "Motivated Strategies for Learning Questionnaire MSLQ" (Pintrich*, et al.*, 1991). MSLQ is a well-established item battery designed to address students' use of learning strategies (for example "I have a regular place set aside for studying" from the subscale "Resource management strategies").





Both scales underwent a revision process: based on students' answers an exploratory analysis including inter-item and item-total correlations plus factor analysis was performed on the first version (27 items) and again after outlying items had been replaced or removed (21 items). The final factor analysis produced one common factor describing "attitude towards mathematics", covering liking mathematics (for example "I am interested in mathematics"; "I enjoy learning mathematics") and self-confidence in learning mathematics (for example "I learn things quickly in mathematics"; "Mathematics is harder for me than any other subject"). Internal consistency of this subscale was acceptable, with Cronbach's α = .82. The scale describing the use of learning strategies was less consistent, Cronbach's α was only .71, and only four items loaded on a common factor that could be described with "mastering the self-study process": these items were related to self-organization and time management (for example "I usually managed to keep to my schedule").

### 2.4 Effort

Students' effort and engagement in the learning process were represented by variables from two different sources: self-reported measures of effort were collected from the evaluation questionnaire (number of learning modules and invested learning time per week) and the LMS log files provided the number of page views per student and the number of completed test attempts. At the end of each learning module students were advised to monitor their progress by taking a self-test, consisting of 10 to 15 randomized items. The data analysis was to reveal which variable showed the strongest explanatory power in relation to learning gains in the pre-course (Macfadyen and Dawson, 2010).

### 2.5 Academic achievement: first and final year

Overall academic achievement was measured by cumulated GPA at the end of the degree programme; a second measure was the dichotomous variable "graduation / withdrawal". For the analysis of students' first year performance a variable was needed that strongly correlated with these measures. Data from the first participating cohort that started the degree programme in 2011 and graduated in 2014 ($n$ = 660) were used for this analysis. Nearly all examinations significantly correlated with GPA, but Mathematics I was the first year exam with the strongest correlation ($r$ = .62; $n$ = 660; $p$ < .01). The simple linear regression model using Mathematics I as a predictor of GPA was significant and explained 38% of the variance in GPA ($n$ = 660; $R^2$ = .38; $R^2$ adj. = .37; $F$ (14, 450) = 405.77; $p$ < .01). Mathematics I was also significantly related to the dichotomous variable graduation / withdrawal: For every increase in grades in Mathematics I grades the odds of completing the degree programme were 14 times greater than the odds of withdrawing ($p$ < .01). Thus the hypothesized relevance of mathematics performance for general academic achievement in engineering was confirmed and Mathematics I grades identified as an early indicator of study success in engineering.

### 2.6 Dataset final analysis

The data collected for the main analysis were based on the cohort that started the degree programme in 2014 and had access to the revised e-learning programme, consisting of a pretest in mathematics, an e-learning environment open for self-study, and optional e-tutoring and face-to-face courses. The following groups of variables were collected from the LMS:

**Table 1:** Collected variables

| | # items |
|---|---|
| **Preconditions when entering tertiary education (traditional predictors)** | |
| Prior knowledge level in mathematics (pretest mean score) | 77 |
| Demographic and personal variables (final school grades, type of school, mathematics grades, gender, age, gap between school and university, federal state) | 7 |
| **Pre-course participation and variables related to effective learning** | |
| Type of course attended (self-study, plus e-tutoring or face-to-face) | 1 |
| Attitude scale | 14 |
| Use of learning strategies | 7 |
| Level of engagement | 5 |
| **First year achievement** | |
| Results Mathematics I exam | 1 |

Of 722 first year students, 603 participated in the pretest and the majority answered the associated questionnaire. The diagnostic test feedback informed students about their test results per mathematical field and advised them to close existing knowledge gaps with the related learning material. (Note: the design of the diagnostic feedback was significantly improved by a Moodle plug-in developed by Dreier (2014) for his bachelor thesis in computer science). 42% of all pretest participants decided to enrol in either additional programme: 119 students visited a face-to-face course and 132 opted for the e-tutoring version. Attrition rate in the e-tutoring course was 14%, so that 113 students completed this course with a certificate. A group of 28 students attended both additional programmes (see table 2). 105 first year students did not participate in the pretest nor the pre-course, but nearly all first year students ($n$ = 708; 98%) participated in the posttest that was taken at the university's computer labs during induction week. For the regression analysis, data from 613 students who took the first year examination Mathematics I six months later were available.

**Table 2:** Pre-course participation and first year students (2014 cohort)

| | *n* |
|---|---|
| **Pre-course participants** | 603 |
| Questionnaire I: personal and attitude scales | 593 |
| Pretest | 603 |
| Self-study* | 386 |
| + E-tutoring course | 85 |
| + Face-to-face course | 91 |
| + E-tutoring and face-to-face course | 28 |
| Questionnaire II: evaluation and learning strategies scales | 200 |
| **Enrolled students** | 722 |
| Posttest | 708 |
| Posttest only | 105 |
| **First year performance** (Mathematics I) | 613 |

## 3. Results

### 3.1 Students' preconditions and academic achievement

Standard multiple regression analysis was employed to investigate the power of personal and demographic variables in predicting first year exam results in Mathematics I. In each of the single and multiple regression models, the two IVs final school grades and pretest results showed significant impact on the dependent variable Mathematics I. The type of secondary school attended was also found an important factor, suggesting significantly poorer MI performance for students from vocational schools, or with non-traditional backgrounds (Faulkner, *et al.*, 2014; van Soom and Donche, 2014). Mathematics grades at school were also related to Mathematics I, but this variable showed less powerful results in the multiple model than expected (Zhang, *et al.*, 2004; Ehrenberg, 2010; Faulkner, *et al.*, 2010). One reason might have been that the data, unlike final school grades, was based on self-reports.

Some interactions between variables were identified, for example between gender, age, and educational background. As female students are underrepresented in engineering courses (in this study the average rate was 12%) it is very difficult to separate the influence of gender on academic achievement in engineering (Ackerman, *et al.*, 2013). In the literature, investigations of the relation between gender and performance in mathematics or science have led to mixed results (Zhang, *et al.*, 2004; Xie and Shauman, 2005; Johnson and Kuennen, 2006; Richardson, *et al.*, 2012; Faulkner, *et al.*, 2014). In this study, female students and younger students, on average, had higher school achievement levels, leading to sometimes contradictory effects in single and multiple regression analyses. A descriptive analysis showed that women were often younger and more often had traditional educational backgrounds and very good secondary school grades than male students. After controlling for these interactions gender was unrelated to achievement, as well as age, the length of the gap between secondary and tertiary education, and the federal state in which secondary school was attended.

The complete model accounted for 33% of variance in first year performance ($n$ = 465; $R^2$ = .33; $R^2$ adj. = .31; $F$ (13, 451) = 16.67; $p$ < .01). Comparing the two most consistent IVs, final school grades and pretest results, the latter was found the strongest predictor of first year performance. After the removal of pretest results from the multiple model, $R^2$ decreased from .33 to .22. When the IV final school grades was removed from the model, $R^2$ decreased to .30. Note that the predictive quality of the diagnostic pretest was considerably improved throughout the four years of the study, with only 25% of variance explained in 2011. Pretest results were also found significantly related to final GPA in a multiple regression with one complete cohort (first year students of 2011), and both variables were significantly related to student withdrawal in a logistic regression.





These outcomes mirror the literature on academic achievement in engineering, with very stable relations between school performance, prior knowledge level, and success in MINT-related subjects (Budny, *et al.*, 1998; Zhang, *et al.*, 2004; Kokkelenberg and Sinha, 2010; Faulkner, *et al.*, 2014; van Soom and Donche, 2014). Students with poor values in any of the achievement-related IVs, but particularly those with a poor pretest result, had a higher risk to perform poorly in Mathematics I.

### 3.2 Learning gains in the pre-course

After having verified the importance of prior knowledge in mathematics for study success in engineering factors influencing learning gains in the pre-course were analysed. In 2014, 603 students participated in both tests and achieved an average pretest score of 49.7 ($SD$ = 15.9) and an average posttest score of 55.2 ($SD$ = 17.5). By comparison, students who had not participated in the pretest achieved a posttest mean score of 47.3 ($SD$ = 18.2). In both groups a large variance in test results could be observed. The average gain score (posttest minus pretest) for the 2014 cohort was 5.4 (median = 5.1), with a maximum value of 61.8 and a minimum of -37.5. Students with poor pretest results (mean score < 50), thus considered the "at risk" group, had an average gain score of 8.3 (median = 7.3; max. = 61.8; min. = -23.4).

#### 3.2.1 Course type

The highest learning gains were achieved by students who had participated in both course types, e-tutoring and face-to-face with an average gain score of 9.1 (n = 28, pretest mean score = 44.2). The remaining 85 e-tutoring participants had a gain score of 6.7, in combination with a pretest result of 47.5. The poorest gains were achieved by students who had attended the face-to-face course, only (gain score = 3.5). This group also had the poorest pretest results, with a mean score of 43.7. Pre-and posttest results per course type are depicted in Table 3 and Figure 1. The 19 students who had withdrawn from the e-tutoring course failed to improve, as well (note that this group includes 6 students who later on attended a face-to-face course).

**Table 3:** Pre- and posttest results 2014: complete dataset in comparison to chosen pre-course type ($n$ = 603) (*6 students participated in a face-to-face course, as well)

| | participants both tests | self-study | face-to-face | e-tutoring | face-to-face + e-tutoring | e-tutoring withdrawal* |
|---|---|---|---|---|---|---|
| n | 603 | 386 | 91 | 85 | 28 | 19 |
| pretest (%) | 49.7 | 52.4 | 43.6 | 47.5 | 44.2 | 38.0 |
| posttest (%) | 55.2 | 57.9 | 47.2 | 54.2 | 53.3 | 39.9 |
| gain score | 5.5 | 5.5 | 3.5 | 6.7 | 9.1 | 1.9 |

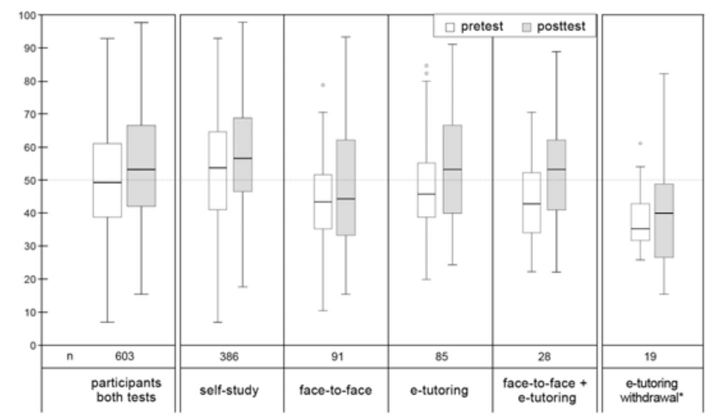



**Figure 1:** Pre- and posttest results 2014: complete dataset in comparison to chosen pre-course type ($n$ = 603) (*6 students participated in a face-to-face course, as well)

Regarding the modular course programme, the strongest effects could be observed for the e-tutoring course, a one-month self-study programme supervised by mathematics lecturers. However, the significance of these results was limited, as students were not randomly assigned but had self-enrolled into the different course types (e-tutoring, face-to-face, self-study, or neither). An analysis of students' educational backgrounds suggested that students with higher "risk"-level, e.g. poorer school performance, or having attended a vocational school, more often chose the weekly face-to-face courses. Furthermore, variance in gains was high for all groups, so that it could be assumed that other factors had an influence on successful pre-course participation.

#### 3.2.2 *Attitude and learning strategies*

It had been hypothesized that mathematics attitude items would correlate with each other, which they did, thus replicating existing results that suggest relations between mathematics liking and mathematics self-confidence (Parsons*, et al.*, 2009). Significant relations with pretest results were also found for nearly all attitude items, so that the presumption that a positive attitude towards mathematics would be related with a higher level of prior knowledge could be verified (Mullis*, et al.*, 2012). A critical point were the often skewed distributions: participants more often expressed positive attitudes towards mathematics, or felt reluctant to express negative attitudes, leading to small case numbers. For example, only 13% ($n$ = 77) of first year students were on the negative side of the statement "I enjoy learning mathematics" (strongly disagree: $n$ = 15; disagree: $n$ = 62), whereas 63% agreed ($n$ = 277) or strongly agreed ($n$ = 89).

Not-normal distributions were also observed for the learning strategies scale. Four items addressing a proficient use of learning strategies were significantly related to each other, and to pretest results, indicating that students able to manage their learning process had a higher level of prior knowledge in mathematics, as well. However, these relations were never linear, so that these variables only allowed to differentiate between students who "strongly agreed" to an item like "I usually managed to keep to my schedule" ($n$ = 43; pretest mean scores = 58.6) and the rest of the sample. Correlations between the attitude and the learning strategies scale were rather weak, as well. With regard to these non-linear patterns analyses of variance were performed for each single item in relation to learning gains in the pre-course. In this process it was found that both scales, students' attitudes towards mathematics and their use of learning strategies, were related to prior knowledge level, but were more or less unrelated to the variable gain score (posttest minus pretest). Thus students with deficits in basic mathematics knowledge only rarely showed a strong positive attitude or high efficiency in their use of learning strategies, but if so this was unrelated to learning gains.

#### 3.2.3 *Effort*

It was expected that students who invested a lot of time and effort into the pre-course would achieve a higher gain score (Ackerman*, et al.*, 2013). Four different measures of effort were available for this analysis. In the evaluation ($n$ = 205), students had answered how many hours per week they had studied. A first analysis suggested that students with more study time per week had poorer pretest results and higher learning gains. It also could be observed that with an increase in number of reported learning modules learning gains increased, as well. ANOVA estimations for these two items, however, were not significant, and showed a high variance in each subgroup's gain scores.

Two further variables were collected from the LMS log files. The number of page views per learning module did not deliver significant results. According to the database query, 83% of the pre-course participants ($n$ = 603) had visited at least one page (note that page views were counted per login, so that the same page was only counted once per login session). The highest number of page views was 1585 (out of 684), but the majority of cases had no more than 200 page views (median = 121). Only 19 students had a page view count above 1000. An ordinal version of this variable was used for ANOVA, grouped to "no views" ($n$ = 101), "1-10 views" ($n$ = 83), "11-100 views" ($n$ = 145), "101-200 views" ($n$ = 77) and "200 and more views" ($n$ = 197). Students with 1-10 page views showed poorer gains than the rest of the sample, but otherwise this item did not significantly explain achievement in the pre-course.

Finally, the number of self-tests per student were related to learning gains. Each learning module provided a final self-assessment, consisting of 10-15 randomized items (thus with each test attempt new items were presented and the number of attempts was unlimited). The highest number of test attempts was 83, but the majority of students took four tests (= median). Transformed to a five-step ordinal variable, with "no test attempts" ($n$ = 296), "1-5 attempts" ($n$ = 167), "6-10 attempts" ($n$ = 55), "11-20 attempts" ($n$ = 60), and "21 and





more attempts" ($n$ = 25), this variable significantly differentiated between higher / lower achievement in the pre-course. Students with no test attempts had the poorest learning gains (gain score = 3.8) and students with 21 and more attempts had an average gain score of 12.0.

These results strongly supported the view that study time or number of page views may be unreliable indicators of student engagement in e-learning environments (Samson, 2015). Macfadyen and Dawson (2010) reported weak relations between these measures and performance in an online biology course. They observed a good predictive power for number of tests completed and an even stronger impact of the total number of forum posts (an effect that could not be confirmed in this study due to low and irregular case numbers in discussion forums).

**Table 4:** Pre- and posttest results 2014: complete dataset in comparison to number of online self-test attempts ($n$ = 603)

| | participants both tests | number of test attempts none | 1 to 5 | 6 to 10 | 11 to 20 | 21 and more |
|---|---|---|---|---|---|---|
| n | 603 | 296 | 167 | 55 | 60 | 25 |
| pretest (%) | 49.7 | 50.2 | 48.2 | 52.0 | 49.9 | 49.0 |
| posttest (%) | 55.2 | 54.0 | 53.7 | 57.2 | 60.4 | 61.0 |
| gain score | 5.5 | 3.8 | 5.6 | 5.3 | 10.5 | 12.0 |

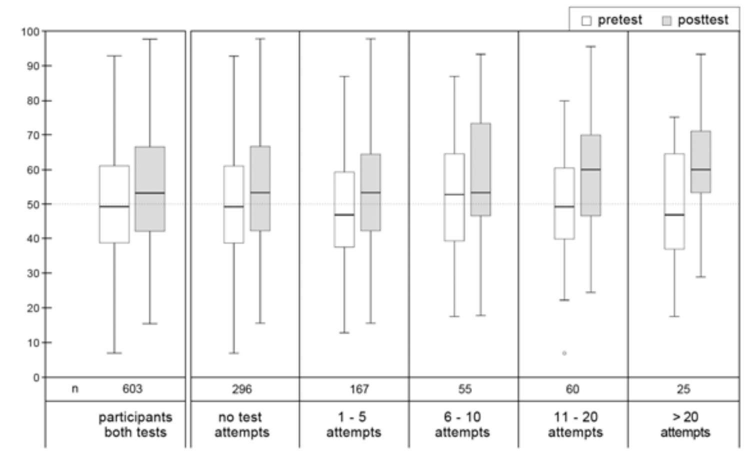



**Figure 2:** Pre- and posttest results 2014: complete dataset in comparison to number of online self-test attempts ($n$ = 603)

### 3.3 Learning gains in the pre-course and academic achievement

In the final analysis, learning gains in the pre-course were related to first year academic achievement. Assuming a poor pretest performance being a risk factor, a high gain score was expected to reduce this risk. Accordingly, gain score as well as learner engagement, represented by number of test attempts, were expected to influence Mathematics I results. Thus in the final analyses these variables were added to the multiple regression as described in section 3.1. Table 5 gives a summary of the changes in variance explained ($R^2$) when pretest results (model 2), gain score (model 3), and effort (model 4) were added to the basic model (model 1). It can be seen that in the basic model 21% of variance in Mathematics I was accounted for. When diagnostic pretest scores were added, $R^2$ increased to .33. Finally, the variables gain score and number of test attempts led to a total variance explained of 36%.

**Table 5:** Summary of hierarchical regression analysis for variables predicting Mathematics I ($n$ = 465). Model 1: students preconditions when entering university; model 2: plus pretest mean score; model 3: plus gain score (pre-course learning gains); model 4: plus measures of effort (number of page views, number of test attempts) ($B$: unstandardized regression coefficient; $SE\ B$: standard error; β: standardized regression coefficient; significance levels: *$p$ < .05; **$p$ < .01)

| | model 1 | | | model 2 | | | model 3 | | | model 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Predictor variable | $B$ | $SE\ B$ | β | $B$ | $SE\ B$ | β | $B$ | $SE\ B$ | β | $B$ | $SE\ B$ | β |
| gender | -.06 | .13 | -.21 | .14 | .12 | .05 | .17 | .12 | .06 | .08 | .12 | .03 |
| age | .03 | .05 | .52 | .03 | .05 | .06 | .04 | .05 | .07 | .04 | .04 | .07 |
| mathematics grades | .30 | .15 | .13* | .00 | .15 | .00 | -.05 | .14 | -.02 | -.28 | .15 | -.13 |
| secondary school grades | .64 | .11 | .33** | .44 | .10 | .23** | .39 | .10 | .20** | .43 | .10 | .23** |
| pretest score | | | | .03 | .00 | .40** | .03 | .00 | .48** | .03 | .00 | .43** |
| gain score | | | | | | | .01 | .00 | .18** | .01 | .00 | .14** |
| number of page views | | | | | | | | | | .00 | .00 | -.01 |
| number of test attempts | | | | | | | | | | .02 | .01 | .11* |
| $R^2$ ($R^2$ adj.) | .21 (.19) | | | .33 (.31) | | | .35 (.33) | | | .36 (.34) | | |
| $F$ for change in $R^2$ | 10.03** | | | 16.67** | | | 17.44** | | | 15.67** | | |

Gain score showed a significant impact on Mathematics I and also added to the variance explained (model 3: $n$ = 465; $R^2$ = .35; $R^2$ adj. = .33; $F$ (14, 450) = 17.44; $p$ < .01). It should be stated that with a $B$ coefficient of .014 the influence of this variable was not very strong; however, according to this model, a student with a gain score of 20 was predicted to achieve a Mathematics I exam that was .28 grades above that of a student with otherwise similar preconditions and a gain score of zero (note that test scores ranged from 0 to 100 and that Mathematics I grades ranged from 1 to 5). The number of test attempts, as well, showed a significant impact on Mathematics I results (model 4), confirming the importance of this variable.

Finally, it was investigated if the group of students who had not participated in the pretest or the pre-course programme ($n$ = 105) differed in their Mathematics I results. The multiple model suggested poorer first year performance when a student had not taken the pretest, and this relation was significant, as well ($p$ < .01). In the "at risk" group, the effect of *not* participating in the pretest led to a difference of -.5 in Mathematics I grades. The effectiveness of the pre-course thus could be established in the multiple model. As a limitation to this interpretation it should be considered that participation was voluntary, therefore groups were not randomized. It may be hypothesized that students who take the diagnostic pretest already show a higher interest in their degree programme, which might result in a better first year performance. Descriptive analyses suggested that the rate of "at risk" students in the posttest-only group was slightly higher, with more students having attended vocational schools and a higher rate of medium to poor school grades. These differences were not significant, with a high variance and a considerable number of very high performing students. Thus non-participation in the pre-course could not be described as a risk factor in itself, but students who were "at risk" in any of the predictive variables certainly would have benefitted from pre-course participation.

## 4. Discussion and conclusion

In this article different dimensions to the evaluation of a web-based pre-course in mathematics were summarized, relating students' preconditions when entering university, their learning activities in the pre-course and first year study success. In order to establish a consistent data model the impact of all collected variables on either learning gains in the pre-course or academic achievement was analysed. In this process, the relevance of "traditional" or performance-related variables for study success in engineering could be confirmed. Secondary school grades, for example, highly correlated with later study success, but the most consistent predictor of first year academic achievement were test results in a web-based diagnostic pretest in mathematics. In the multiple regression model this variable significantly influenced first year performance as well as cumulated GPA at the end of the degree programme, identifying poor pretest results as a dominant risk factor. These outcomes confirmed existing literature (Zhang*, et al.*, 2004; Ackerman*, et al.*, 2013; Faulkner*, et al.*, 2014) and indicated that the diagnostic pretest delivered consistent results. The model also showed a significant impact for the variable pre-course learning gains (pre-posttest difference); "at risk" students who were able to considerably improve throughout the pre-course showed better first year performance.





It then was investigated which factors most strongly supported successful pre-course participation. As the course was designed to address a heterogeneous group of learners and allowed self-enrolment into different modules some limitations regarding the interpretation of outcomes had to be considered. The highest pre-course learning gains, for example, were achieved by students who had combined two additional course programmes, e-tutoring and face-to-face, followed by e-tutoring-only participants. Students who had preferred to learn independently with the self-study programme were also able to improve considerably, whereas the face-to-face group had the least learning gains. Effects of course participation could even be linked to exam scores in Mathematics I, with significantly poorer results for the face-to-face group. Three interpretations of these unexpected results are suggested. First, reliability issues had to be taken into account as results were not based on randomized groups. Face-to-face courses appeared to be preferred by "at risk" students (non-traditional, poorer school grades, poorer pretest-results) and although the differences between this group and the e-tutoring group were not significant students' diverse preconditions may have added up and influenced the outcomes. Second, the face-to-face and e-tutoring course were difficult to compare regarding length, intensity, and concept. It may be hypothesized that the one-week face-to-face was too condensed to have a lasting effect on students with major knowledge gaps. The one-month e-tutoring course allowed for more practice, and with weekly tasks and a final certificate the learning process was monitored more strongly. A third reason might be that face-to-face participants felt less inclined to invest extra time into self-study once they had completed the course. For this group little or no online learning activity could be observed. Concluding, these results called for a revision of the face-to-face course concept, for example by expanding it to a four-week blended learning programme, giving students more time for individual practice.

Affective and metacognitive variables in this study were more or less unrelated to learning gains. Attitude towards mathematics, for example, strongly correlated with prior performance, suggesting that students with good grades also have a positive attitude towards the subject (Kadijevich, 2006; Mullis*, et al.*, 2012). A significant impact on students' learning gains in the pre-course, though, could not be observed. Even less related to learning gains was a scale addressing students' use of learning strategies (Pintrich*, et al.*, 1991; Schiefele and Wild, 1994). Distributions were often skewed and many items produced inconsistent results, being unrelated to prior knowledge level, learning gains, or the attitude scale. It is suggested that the weak impact of this scale might have been caused by a lack of representativeness. Only a third of the sample participated in the final evaluation survey and the learning strategies items in particular were often left unanswered, leading to even smaller case numbers. It also may be hypothesized that a superficial answer behaviour in the evaluation affected the quality of the scales (Spooren*, et al.*, 2013). It also has been reported that low-performing students are less likely to conscientiously answer questionnaires which also may have led to skewed answer patterns (Thiessen and Blasius, 2008). Summarizing, the impact of the meta-cognitive scales was disappointing. In order to better understand learner behaviour in an open e-learning environment a qualitative approach might be more beneficial.

One variable, however, led to consistent and unmoderated results: "at risk" students who had repeatedly engaged in online self-assessments achieved higher pre-course learning gains than "at risk" students who had not. Compared to other approaches, like invested time, number of learning modules, or number of page views, the number of test attempts thus was found the strongest indicator of effort, or student engagement. This outcome may be characteristic of the domain of mathematics, but similar observations were made by Macfadyen and Dawson (2010) for a web-based biology course. This variable also showed a significant relation to first year performance in the multiple model, suggesting that students with low prior knowledge level in mathematics were able to benefit from the pre-course, but only if they showed a strong learner engagement.

Concluding, it is stated that even volatile and inconsistent learning environments can produce valuable information, but the described limitations will have to be considered when interpreting the results. In order to identify consistent variables external references should be included in the model, in this case students' educational backgrounds and academic achievement. In this study, reliable and significant effects were mainly observed for straightforward quantitative measures, like pre- and posttest results. Further research might be needed into the reliability of affective and motivational items collected from web-based courses. Regarding the effectiveness of student learning, the role of practice should be investigated more deeply (Gibbs and Simpson, 2004; Pachman*, et al.*, 2013). Participants of the pre-course appeared to highly appreciate the possibility to practise online. By providing open question banks related to adaptive tests that provide item sets of different difficulty and complexity levels individual students' learning processes might be supported even better.

## Acknowledgements

Support for this publication was provided by the German Federal Ministry of Education and Research (BMBF) in the context of the Federal "Quality pact for teaching" (ref. number 01PL12012). Responsibility for the content published in this article, including any opinions expressed therein, rests exclusively with the author. Test items and learning material are licensed under the creative commons attribution 3.0 unported and can be provided via www.optes.de.

## References

Ackerman, P.L., Kanfer, R. and Beier, M.E. (2013). Trait Complex, Cognitive Ability, and Domain Knowledge Predictors of Baccalaureate Success, STEM Persistence and Gender Differences. *Journal of Educational Psychology*, 105(3), 911–927.

Ashby, J., Sadera, W.A. and Mcnary, S.W. (2011). Comparing student success between developmental math courses offered online, blended, and face-to-face. *Journal of Interactive Online Learning*, 10(3), 128–140.

Budny, D., LeBold, W. and Bjedow, G. (1998). Assessment of the Impact of Freshman Engineering Courses. *Journal of Engineering Education*, 87(4), 405–411.

Campbell, J.P. and Oblinger, D.G. (2007). Academic Analytics. *EDUCAUSE Learning Initiative*.

Cook, C., Heath, F. and Thompson, R.L. (2000). A meta-analysis of response rates in web- or internet-based surveys. *Educational and psychological measurement*, 60(6), 821–836.

Corrigan, O., Glynn, M., KcKenna, A., Smeaton, A. and Smyth, S. (2015). Student Data: Data is Knowledge. Putting the Knowledge Back in the Students' Hands, 29-30 Oct, Hatfield, UK.

Creswell, J.W. and Plano Clark, V.L. (2011). *Designing and conducting mixed methods research*. Sage, Los Angeles, CA.

Croft, A.C., Harrison, M.C. and Robinson, C.L. (2009). Recruitment and retention of students – an integrated and holistic vision of mathematics support. *International Journal of Mathematical Education in Science and Technology*, 40(1), 109–125.

Dreier, O. (2014). Entwicklung eines Moodle Plug-Ins zur erweiterten Auswertung von Tests. Bachelor Thesis, Duale Hochschule Baden-Wuerttemberg, Mannheim.

Ehrenberg, R.G. (2010). Analyzing the factors that influence persistence rates in STEM field, majors: Introduction to the symposium. *Economics of Education Review*, 29, 888–891.

Fan, W. and Yan, Z. (2010). Factors affecting response rates of the web survey: A systematic review. *Computers in Human Behavior*, 26, 132–139.

Faulkner, F., Hannigan, A. and Fitzmaurice, O. (2014). The role of prior mathematical experience in predicting mathematics performance in higher education. *International Journal of Mathematical Education in Science and Technology*, 45(5), 648–667.

Faulkner, F., Hannigan, A. and Gill, O. (2010). Trends in the mathematical competency of university entrants in Ireland by leaving certificate mathematics grade. *Teaching mathematics and its applications*, 29(2), 76–93.

Gasiewski, J., Eagan, M., Garcia, G., Hurtado, S. and Chang, M. (2012). From Gatekeeping to Engagement: A Multicontextual, Mixed Method Study of Student Academic Engagement in Introductory STEM Courses. *Research in Higher education*, 53(2), 229–261.

Gibbs, G. and Simpson, C. (2004). Conditions under which assessment supports student learning. *Learning and Teaching in Higher Education*, 1(1), 3–31.

Hambleton, R.K. and Swaminathan, H. (2010). *Item response theory. Principles and applications*. Kluwer Academic Publishers, Boston.

HEFCE (2013). *Non-continuation rates at English HEIs. Trends for entrants 2005-06 to 2010-11.* Higher Education Council for England.

Howson, A.G., Barnard, A.D., Crighton, D.G., et al. (1995). Tackling the mathematics problem. Joint report by London Mathematical Society, Institute of Mathematics and its Applications, Royal Statistical Society.

Jackson, D.C. and Johnson, E.D. (2013). A hybrid model of mathematics support for science students emphasizing basic skills and discipline relevance. *International Journal of Mathematical Education in Science and Technology*, 44(6), 846–864.

Johnson, M. and Kuennen, E. (2006). Basic Math Skills and Performance in an Introductory Statistics Course. *Journal of Statistics Education*, 14(2).

Kadijevich, D. (2006). Developing Trustworthy Timss Background Measures: A Case Study On Mathematics Attitude. *The Teaching of Mathematics No.* 2, pp. 41–51.

Kane, M.T. (2013) Validating the Interpretations and Uses of Test Scores. *Journal of Educational Measurement*, 50(1), 1–73.

Kokkelenberg, E. and Sinha, E. (2010). Who succeeds in STEM studies? An analysis of Binghamton University undergraduate students. *Economics of Education Review*, 29, 935–946.

Lawson, D. (2000). Changes in the Competency of A Level Students. *Measuring the Mathematics Problem*, London, 6–9.

Macfadyen, L.P. and Dawson, S. (2010). Mining LMS data to develop an 'early warning system' for educators: A proof of concept. *Computers & Education*, 54(2), 588–599.

Mullis, I.V.S., Martin, M.O., Foy, P. and Arora, A. (2012). *TIMSS 2011 International Results in Mathematics*.





Pachman, M., Sweller, J. and Kalyuga, S. (2013). Levels of knowledge and deliberate practice. *Journal of Experimental Psychology: Applied*, 19(2), 108–119.

Pappano, L. (2012). The Year of the MOOC, *The New York Times, Education Life Supplement* Nov 4, p. 26.

Parker, M. (2005). Placement, Retention, and Success: A Longitudinal Study of Mathematics and Retention. *Journal of General Education*, 54(1), 22–40.

Parsons, S.J., Croft, T. and Harrison, M. (2009). Does students' confidence in their ability in mathematics matter?. *Teaching mathematics and its applications*, 28(2), 52–68.

Pintrich, P.R., Smith, D.A.F., Garcia, T. and McKeachie, W.J. (1991). *A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ).* Ann Arbor, Michigan.

Richardson, M., Abraham, C. and Bond, R. (2012). Psychological Correlates of University Students' Academic Performance: A Systematic Review and Meta-Analysis. *Psychological Bulletin*, 138(2), 353–387.

Richey, R.C. and Klein, J.D. (2005). Developmental research methods: Creating knowledge from instructional design and development practice. *Journal of Computing in Higher Education*, 16(2), 23–38.

Robbins, S.B., Lauver, K., Le, H., Davis, D., Langley, R. and Carlstrom, A. (2004). Do psychosocial and study skill factors predict college outcomes? A meta-analysis. *Psychological Bulletin*, 130(2), 261–288.

Romero, C. and Ventura, S. (2010). Educational Data Mining: A Review of the State of the Art. *Transactions on systems, man, and cybernetics, Part C: Applications and reviews*, 40(6), 601–618.

Samson, P.J. (2015). Can Student Engagement be Measured? and, if so, Does it Matter?. *Frontiers in Education Conference FIE*, El Paso, Texas, 21-24 Oct. 2015.

Schiefele, U. and Wild, K.P. (1994). Lernstrategien im Studium: Ergebnisse zur Faktorenstruktur und Reliabilität eines neuen Fragebogens, *Zeitschrift für Differentielle und Diagnostische Psychologie*, 15(4), 185–200.

Smith, G.G. and Ferguson, D. (2005), Student attrition in mathematics e-learning, *Australasian Journal of Educational Technology*, 21(3). 323–334.

Spooren, P., Brockx, B. and Mortelmans, D. (2013). On the Validity of Student Evaluation of Teaching: The State of the Art. *Review of Educational Research*, 83(4), 598–642.

Street, H. (2010), Factors Influencing a Learner's Decision to Drop-Out or Persist in Higher Education Distance Learning. *Online Journal of Distance Learning Administration*, 13(4).

Thiessen, V. and Blasius, J. (2008). Mathematics achievement and mathematics learning strategies: Cognitive competencies and construct differentiation. *International Journal of Educational Research*, 47(6), 362–371.

van Soom, C. and Donche, V. (2014). Profiling First-Year Students in STEM Programs Based on Autonomous Motivation and Academic Self-Concept and Relationship with Academic Achievement. *PLoS one*, 9(11), e112489.

Warwick, J. (2007). A Pilot Study in the Application of the Analytic Hierarchy Process to Predict Student Performance in Mathematics. *PRIMUS*, 17(1), 181–194.

Xie, Y. and Shauman, K.A. (2005). *Women in science. Career processes and outcomes*. Harvard University Press, Cambridge, MA.

Zhang, G., Anderson, T.J., Ohland, M.W. and Thorndyke, B.R. (2004). Identifying factors influencing engineering student graduation: A longitudinal and crossinstitutional study. *Journal of Engineering Education*, 93, 313–320.

A.3 Derr, K.; Hübl, R.; Mechelke-Schwede, E.; Podgayetskaya, T., Weigel, M. (2017): “Predicting study success in engineering? Evaluation of learner data” (Original title: Vorhersage von Studienerfolg in den Ingenieurwissenschaften über Learning Analytics? Aussagekraft von Lernerdaten in einem webbasierten Mathematik-Vorkurs. In U. Kortenkamp and A. Kuzle (eds.): Beiträge zum Mathematikunterricht, WTM, Münster, pp. 1297–1300.

DOI: http://dx.doi.org/10.17877/DE290R-18569

https://eldorado.tu-dortmund.de/bitstream/2003/36568/1/BzMU-2017-DERR-2.pdf

Katja DERR, Reinhold HÜBL, Edith MECHELKE-SCHWEDE, Tatyana PODGAYETSKAYA, Miriam WEIGEL, Mannheim

# Vorhersage von Studienerfolg in den Ingenieurwissenschaften über Learning Analytics? Aussagekraft von Lernerdaten in einem webbasierten Mathematik-Vorkurs

## 1 Ausgangslage

In ingenieurwissenschaftlichen Studiengängen werden solide Grundkenntnisse in Mathematik vorausgesetzt; sind diese Kenntnisse lückenhaft, kann schon die Studieneingangsphase zu einer permanenten Überforderung werden. Vor- und Brückenkurse in Mathematik sollen angehende Studierende auf die Anforderungen eines Studiums vorbereiten und damit auch der wachsenden Zahl der Studienabbrüche entgegenwirken. Da diese Angebote dem Regelstudium vorgeschaltet sind und nicht alle Studienanfänger/-innen erreichen ist es allerdings schwierig, ihren Einfluss auf den späteren Studienerfolg zu analysieren.

An der Dualen Hochschule Baden-Württemberg Mannheim werden im Rahmen des QPL-Verbundprojekts *optes* die Daten von Teilnehmer/-innen an einem webbasierten Vorkurs analysiert und mit dem Studienerfolg im ersten Studienjahr und am Ende des Studiums in Beziehung gesetzt. Neben demografischen und schulbezogenen Daten werden seit 2011 die Vorkenntnisse in Mathematik und der Lernerfolg im Vorkurs über einen Einstiegs- und einen Kontrolltest erhoben; seit 2014 werden zusätzlich Fragebögen zur Einstellung gegenüber dem Fach Mathematik und den eingesetzten Lernstrategien ausgewertet, ergänzt durch Logfiles des Lernmanagementsystems. Der Vorkurs ist modular aufgebaut, d.h. zusätzlich zum Selbststudium können Studierende an Präsenzkursen oder einem betreuten eLearning Angebot teilnehmen.

## 1 Leistungen im Fach Mathematik und Studienerfolg

Zunächst wurde untersucht, ob die Relevanz des Fachs Mathematik für den Studienerfolg in einem ingenieurwissenschaftlichen Studiengang für die Fakultät Technik der DHBW Mannheim belegt werden kann (Studiengänge Informationstechnik, Elektrotechnik, Maschinenbau, Mechatronik und Wirtschaftsingenieurwesen). Für diese Untersuchung wurden die anonymisierten Datensätze von drei kompletten Jahrgängen betrachtet (2011: n= 660; 2012: n = 779; 2013: n = 665). Als Maß für „Studienerfolg" stand der kumulierte GPA (Grade Point Average) am Ende des Studiums zur Verfügung, sowie die dichotome Variable „Studium abgeschlossen (ja/nein)". Fast alle Klausurergebnisse korrelierten signifikant mit dem GPA; der stärkste Zusammenhang mit Leistungen aus dem ersten Studienjahr wurde für die Klausur Mathematik I festgestellt, mit Korrelationen zwischen $r$ = .62 und .70 ($p < .01$). In einer linearen Regression konnte über die Variable Mathematik I mehr als 30% der Varianz im kumulierten GPA erklärt werden, höhere Werte wurden nur für die Klausur Mathematik II erzielt, die im zweiten bzw. dritten Studienjahr geschrieben wird ($R^2$ über 40%). Mathematik I zeigte auch einen Einfluss auf die Variable „Studienabbruch": In einer logistischen Regression stieg mit jedem Anstieg in Mathematik I die Wahrscheinlichkeit das Studium abzuschließen signifikant und deutlich an (Werte für Exp. (B) zwischen 5 und 14). Allerdings war die Varianz in diesen Berechnungen sehr hoch; eine zuverlässige „Vorhersage" des Studienabbruchs auf Basis der Mathematik I Klausur konnte aus den Daten nicht abgeleitet werden.

Trotzdem zeigen die Ergebnisse, dass ein starker Zusammenhang zwischen den Leistungen im Fach Mathematik und dem Studienerfolg in den fünf untersuchten ingenieurwissenschaftlichen Studiengängen besteht – und dass die erste Mathematikklausur im Vergleich zu anderen Studienfächern einen guten frühen Indikator für den späteren Studienerfolg darstellt.

## 2 Eingangsvoraussetzungen und Studienerfolg

Im nächsten Schritt wurde der Einfluss der Eingangsvoraussetzungen der Studienanfänger/-innen auf den Studienerfolg im ersten Semester untersucht. Neben klassischen Prädiktoren wie der Abschlussnote im Zeugnis der Hochschulzugangsberechtigung (HZB) oder der Schul-Mathematiknote wurde die Art der HZB erhoben, außerdem das Bundesland, in dem die HZB erworben wurde, das Alter der Studienanfänger/-innen, der Abstand zwischen Schule und Hochschule, sowie das Geschlecht.

Als zusätzliche fachbezogene Variable lagen die Ergebnisse in einem diagnostischen Einstiegstest vor, der zu Beginn des Mathematik-Vorkurses online durchgeführt wurde. Inhaltlich deckte der Test den Schulstoff der Mittel- und Oberstufe ab (siehe Empfehlungen der cosh Arbeitsgruppe, 2014).

Über einfache und multiple Regressionen wurde der Einfluss der demografischen und schulbezogenen Variablen auf die Leistungen im ersten Studienjahr analysiert. Den stärksten und in allen Berechnungen signifikanten Einfluss auf Mathematik I hatte das Ergebnis im diagnostischen Einstiegstest, gefolgt von der Gesamtnote im Schul-Abschlusszeugnis (HZB-Note) (vgl. z.B. Faulkner et al., 2014; Greefrath & Hoever, 2016). Weniger deutlich war der Effekt der Mathematik-Schulnote, diese Variable korrelierte zwar im einfachen linearen Vergleich mit Mathematik I, war im multiplen Modell aber deutlich schwächer als der Einstiegstest oder die HZB-Note.

In Institut für Mathematik der Universität Potsdam (Hrsg.), *Beiträge zum Mathematikunterricht 2017* (S. x–y). Münster: WTM-Verlag

Bezüglich der Hochschulzugangsberechtigung konnte ein signifikanter Unterschied zwischen Studienanfänger/-innen mit gymnasialem Abitur und Fachhochschulreife festgestellt werden (z.B. Knospe, 2011), allerdings war dieser Effekt weniger konsistent als der Einfluss der HZB-Note. Insbesondere in der Gruppe der Absolventen von Gymnasien mit Abitur (ca. 70% der Studienanfänger/-innen) waren große Leistungsunterschiede in Mathematik zu beobachten.

In der Literatur wurde wiederholt auf die Bedeutung von Mathematik-Leistungskursen auf Eingangstestergebnisse bzw. Studienerfolg hingewiesen (z.B. Knospe, 2011; Greefrath & Hoever, 2016). Diese Daten lagen für die vorliegende Untersuchung leider nicht vor. In Baden-Württemberg erhalten alle Oberstufenschüler/-innen vierstündigen Mathematik-Unterricht, eine Vertiefung über Leistungskurse ist nicht vorgesehen. Vor diesem Hintergrund sind die relativ schwachen Testergebnisse der Schüler/-innen aus Baden-Württemberg im Vergleich zu den beiden anderen Einzugsgebieten von Mannheim (Rheinland-Pfalz und Hessen) sicherlich erwähnenswert.

Insgesamt zeigen die Ergebnisse, dass Vorkenntnisse in Mathematik einen guten Prädiktor für den späteren Studienerfolg darstellen, und dass Studienanfänger/-innen mit einem unterdurchschnittlichen Einstiegstestergebnis eine schlechtere Startposition im Studium haben. Über das multiple Modell konnte 33% der Varianz in Mathematik I erklärt werden ($n = 465$; $R^2 = .33$; $R^2$ adj. = .31; $F$ (13, 451) = 16.67; $p < .01$), ein Wert der vergleichbaren Studien zum Zusammenhang zwischen Eingangsvoraussetzungen und akademischer Leistung entspricht (Ackerman et al., 2013).

## 3 Vorkurs-Teilnahme

Im Zentrum der Vorkurs-Evaluation stand die Frage, ob „Risiko"-Studierende durch die Teilnahme am Mathematik-Vorkurs ihre Startposition verbessern konnten. Tatsächlich zeigte die Variable „Lernerfolg" (Differenz zwischen Kontrolltest und Einstiegstest) in der multiplen Regression einen signifikanten, wenn auch nicht sehr starken Effekt auf die Leistungen im ersten Semester. Das heißt, nur eine erhebliche Verbesserung zwischen Einstiegs- und Kontrolltestergebnis führte zu einem sichtbaren Anstieg der Mathematik I Note.

Der Lernerfolg im Vorkurs wiederum war abhängig vom Engagement der Lernenden. Ein zuverlässiger Faktor zur „Messung" dieses Engagements war die Anzahl der durchgeführten Selbsttests. Es konnte ein linearer Zusammenhang zwischen der Anzahl der Abschlusstests der Online Lernmodule und dem Lernzuwachs im Vorkurs beobachtet werden. Diese Variable zeigte sogar einen signifikanten Einfluss auf die Mathematik I Ergebnisse im multiplen Modell. Ein weiteres Indiz für Lernerfolg im Vorkurs war die angegebene Lernzeit, während andere lernerbezogene Daten, wie der effektive Einsatz von Lernstrategien, die Einstellung dem Fach Mathematik gegenüber oder die Anzahl der besuchten Lernmodulseiten, keinen Einfluss auf die Leistungen der „Risiko"-Studierenden hatte.

Die Analysen legen nahe, dass es für Studierende mit lückenhaften Vorkenntnissen in Mathematik sehr schwer ist, ihre Startposition zu verbessern bzw. den Abstand zu Studienanfänger/-innen mit guten Vorkenntnissen zu verringern. Der Mathematik-Vorkurs zeigte nur dann einen positiven Effekt auf die Leistungen im ersten Studienjahr, wenn die Teilnehmer/-innen zu intensivem Selbststudium bereit waren. Generell ist zu sagen, dass ein Vorkurs nicht das geeignete Mittel ist, um den Schulstoff der Mittel- und Oberstufe neu zu erarbeiten; für angehende Studierende, die in fast allen Themengebieten Nachholbedarf haben, sollte über weitergehende Maßnahmen nachgedacht werden.

In Bezug auf das Datenmodell ist zu sagen, dass ein großer Teil der Varianz in Mathematik I unerklärt bleibt und dass weitere Einflussfaktoren erhoben werden müssten, um auf Basis der Vorkurs-Daten individuelle Prognosen für den Studienverlauf zu erstellen. In der Gesamt-Betrachtung sind die Ergebnisse dennoch sehr aufschlussreich. Der Vergleich der Einstiegstestergebnisse der letzten vier Jahrgänge lässt beispielsweise den Schluss zu, dass die Heterogenität der Vorkenntnisse der Studienanfänger/-innen zunimmt, so dass die Vorkursangebote möglicherweise noch deutlicher ausdifferenziert werden müssen.

## Literatur

Ackerman, P. L., Kanfer, R. & Beier, M. E. (2013). Trait Complex, Cognitive Ability, and Domain Knowledge Predictors of Baccalaureate Success, STEM Persistence and Gender Differences. *Journal of Educational Psychology*, *105* (3), 911–927.

cosh cooperation schule:hochschule (2014). *Mindestanforderungskatalog Mathematik (2.0) der Hochschulen Baden-Württembergs für ein Studium von WiMINT-Fächern*

Faulkner, F., Hannigan, A. & Fitzmaurice, O. (2014). The role of prior mathematical experience in predicting mathematics performance in higher education. *International Journal of Mathematical Education in Science and Technology*, *45* (5), 648–667.

Greefrath, G. & Hoever, G. (2016). Was bewirken Mathematik-Vorkurse? Eine Untersuchung zum Studienerfolg nach Vorkursteilnahme an der FH Aachen. In: A. Hoppenbrock et al. (Hrsg.), *Lehren und Lernen von Mathematik in der Studieneingangsphase. Herausforderungen und Lösungsansätze* (S. 517–530). Berlin: Springer Spektrum.

Knospe, H. (2011). Der Eingangstest Mathematik an Fachhochschulen in Nordrhein-Westfalen von 2002 bis 2010. Proceedings des 9. Workshops Mathematik für ingenieurwissenschaftliche Studiengänge. *Wismarer Frege-Reihe* (2), 8–13.

A.4 Derr, K.; Hübl, R.; Podgayetskaya, T. (2016): “Potential and limitations to the use of formative e-assessment and automated feedback in online pre-courses” (Original title: Formatives eAssessment in Online-Brückenkursen: Potentiale und Grenzen und die Rolle des Feedback). In: Institut für Mathematik und Informatik der Pädagogischen Hochschule Heidelberg (eds.): Beiträge zum Mathematikunterricht, WTM, Münster, pp. 1145–1148.

DOI: http://dx.doi.org/10.17877/DE290R-17587

https://eldorado.tu-dortmund.de/bitstream/2003/35546/1/BzMU16%20DERR%20eAssessment.pdf

Katja DERR, Reinhold HÜBL, Tatyana PODGAYETSKAYA, Mannheim

# Formatives eAssessment in Online-Brückenkursen: Potentiale und Grenzen und die Rolle des Feedback

## 1 Einleitung

Unterstützungsangebote für die Studieneingangsphase und den Übergang Schule / Hochschule haben als Reaktion auf eine gestiegene Nachfrage in Studierendenschaft (Bargel, 2015) und als Maßnahme, um der hohen Heterogenität der Studienanfänger/-innen zu begegnen deutlich zugenommen. Allein im Förderprogramm Qualitätspakt Lehre sind 125 Projekte diesem Themenfeld zugeordnet (BMBF, 2011). Im QPL-Verbundprojekt *optes* werden Methoden und Konzepte zur Optimierung des begleiteten Selbststudiums in einem Online-gestützten Mathematik Vorkurs entwickelt und erprobt. Der (Selbst-)Lernprozess wird durch verschiedene didaktische und technische Maßnahmen strukturiert und gefördert (Halm et al., 2013; Samoila et al., 2016; Daniel & Wingerter, 2015). Im Teilprojekt „formatives eAssessment", das an der Dualen Hochschule Baden-Württemberg Mannheim angesiedelt ist, wurde ein Online-Fragepool der Grundlagenmathematik erstellt, der mittlerweile als offene Ressource zur Verfügung steht.

## 2 Formatives eAssessment

Der Einsatz formativer eAssessments lässt sich unterschiedlichen didaktische Zielen zuordnen, vom Impuls zu Beginn einer Lerneinheit über das Einüben des Gelernten bis hin zur Prüfungsvorbereitung, bzw. summativen eAssessments (Shavelson et al., 2008). Je nach Einsatzgebiet ist zu überlegen, welche Art von Aufgaben, und welche Form des automatisierten Feedback geeignet sind. Neben der einfachen Rückmeldung, ob eine Frage richtig oder falsch beantwortet wurde („Verifikationsfeedback") sind verschiedene Formen des erweiterten Feedback („Elaborationsfeedback") möglich (vgl. Renkl, 1991). Neben der erwarteten Antwort können z.B. Musterlösungen, Kommentare und Bewertungen ausgegeben werden. Im *optes*-Projekt wird unterschieden zwischen *diagnostischem* Feedback auf Tests, die zur Erfassung des Lernstandes zu Beginn oder zum Abschluss des Lernprozesses stehen und *formativem* Feedback, das sich auf die Bearbeitung einzelner Übungsaufgaben bezieht.

## 3 Diagnostisches Feedback auf einen Test

Zu Beginn des Vorkurses haben die Teilnehmer die Möglichkeit, ihr Vorwissen über einen diagnostischen Einstiegstest zu überprüfen. Am Standort Mannheim umfasst dieser Test 77 Aufgaben aus zehn Themengebieten der gymnasialen Mittel- und Oberstufe (basierend auf cosh, 2014), für deren Bearbeitung 120 Minuten zur Verfügung stehen. Um aufgabenspezifische oder technische Einflüssen zu minimieren, kommen im diagnostischen Einstiegstest ausschließlich niederschwellige Online-Aufgabentypen zum Einsatz, die keine besonderen Vorkenntnisse wie z.B. die Eingabe von Formeln erfordern. Dies sind geschlossene Fragetypen, also alle Formen von Multiple Choice (Martinez, 1999), und halb offene Fragetypen, die die Eingabe von numerischen Werten verlangen. Soweit möglich, adressiert jede Aufgabe nur ein Thema (z.B. „Termumformungen" im Themengebiet „Arithmetik"), damit das Ergebnis zur Berechnung des diagnostischen Feedback genutzt werden kann. Neben dem Gesamtergebnis beinhaltet dieses die Bewertung der Vorkenntnisse pro Themengebiet. Bei geringen Kenntnissen wird eine Lernempfehlung für dieses Thema ausgesprochen, inklusive Links zu passenden Lernmaterialien.

Die Aufgabe des diagnostischen Feedback ist die „Kalibrierung" (Winne, 2004), also der Abgleich der Kenntnisse der Lernenden mit den Lernzielen des Vorkurses. Im Fokus steht das (An-)Erkennen von Wissensdefiziten (so denn vorhanden), eine Fehleranalyse pro Aufgabe findet im diagnostischen Feedback nicht statt (siehe Tabelle 1).

Analog zum Einstiegstest (Pretest) erfolgt ein abschließender „Kontrolltest" (Posttest) zu Beginn des Studiums zur individuellen Lernerfolgskontrolle, sowie der Evaluation des Programms. Dieser wird in den Räumen der DHBW Mannheim mit allen Studienanfänger/-innen der Fakultät Technik durchgeführt. So können auch die Vorkenntnisse der Studienanfänger/-innen erhoben werden, die nicht am Vorkurs teilgenommen haben.

## 4 Formatives Feedback auf eine Aufgabe

Im Verlauf des Lernprogramms erhalten die Lernenden immer wieder die Möglichkeit, Übungsaufgaben oder Kurztests zu einem Themengebiet zu bearbeiten. Zu Beginn eines Kapitels kommen eher einfache und wenig komplexe Übungsaufgaben zum Einsatz, um das Gelernte zu wiederholen und mathematische Routinen einzuüben. Sofern möglich, werden Anwendungsbeispiele gegeben. Diese können dann zu einem späteren Zeitpunkt in etwas komplexere und anspruchsvollere Aufgaben eingekleidet werden. Neben Multiple Choice und numerischer Eingabe ist für den Bereich der Übung auch der Fragetyp STACK sehr gut geeignet, der die Eingabe von mathematischen Formeln über AsciiMath Syntax erlaubt (Sangwin, 2013).

Beim formativen Feedback auf Übungsaufgaben stehen der Lösungsweg und das Verständnis eines konkreten mathematischen Problems im Vordergrund. Neben der Rückmeldung, welche Antwort erwartet und vom System

In J. Roth & J. Ames (Hrsg.): *Beiträge zum Mathematikunterricht 2016*. WTM-Verlag, Münster, 2016, S. x-y

als „richtig“ gewertet wurde, erhalten die Teilnehmer eine detaillierte Musterlösung. Bei Multiple Choice Aufgaben ist es außerdem möglich, das Fehlerfeedback zu einzelnen Distraktoren durch Kommentare zu ergänzen (z.B. „Hier haben Sie möglicherweise Zähler und Nenner vertauscht.“).

| | *Verifikations-feedback* (Richtig/Falsch) | *Erweitertes Feedback* | | | |
|---|---|---|---|---|---|
| | | Lösung | Muster-lösung | Kom-mentar | Bewer-tung |
| Diagnostisches Feedback auf einen Test | x | | | x | x |
| Formatives Feedback auf eine Aufgabe | x | x | x | x | x |

**Tabelle 1: Feedbackformate (Diagnostisches und Formatives Feedback)**

## 5 Grenzen des automatisierten Feedback

Die genannten geschlossenen und halb offenen Aufgabenformate decken einen weiten Bereich des Lernprozesses ab, und durch die Weiterentwicklung adaptiver Verfahren ist in der Zukunft mit deutlich optimierten individualisierten Feedbackformaten zu rechnen (siehe die Beiträge der moderierten Sektion DTA in diesem Band). Komplett offene Aufgabenformate, bei denen individuelle (Problem-)Lösungsansätze analysiert werden, erfordern jedoch nach wie vor die Rückmeldung (menschlicher) Expert/-innen.

Im Vorkursprogramm der DHBW Mannheim werden offene Aufgaben im einmonatigen Zusatzangebot „Betreutes eLearning“ genutzt. Die Lernenden laden wöchentlich ihre Lösungen zu einem Aufgabenblatt hoch, inklusive Herleitungen und einzelner Rechenschritte. Da die Studienanfänger/-innen nicht über die nötigen Syntaxkenntnisse zur Eingabe mathematischer Ausdrücke verfügen, wird mit gescannten oder fotografierten handschriftlichen Unterlagen gearbeitet; die PDF-Dokumente werden dann von den Dozent/-innen in der Lernplattform kommentiert und mit den Lernenden diskutiert. Das Verfahren ist aufwändig, und die klaren Vorteile von Online-Fragetypen, wie schnelles Feedback und bessere Lesbarkeit der Eingaben, fallen weg. Dieser Fragetyp liefert aber wichtigen Zusatznutzen im eLearning, da nur über offene Aufgabenformate Leistungen abgefragt und gewürdigt werden können, die außerhalb eines vorgefertigten Antwortspektrums liegen. Durch das Notieren der eigenen Rechenschritte wird die Fähigkeit zur Darstellung von und Kommunikation über mathematische Lösungsansätze gefördert.

## 6 Ausblick

Eine wichtige Aufgabe der verbleibenden Förderphase ist die Entwicklung von Konzepten zur Verwaltung und Nutzung großer Fragepools. Aktuell sind 860 Items im *optes*-Pool, die nach Themengebieten, Fragetypen und Schwierigkeitsgraden sortiert sind. In Kooperation mit der ILIAS Special Interest Group Mathematik wird nach Lösungen gesucht, das Finden und Aktualisieren von Aufgaben für Partnerhochschulen zu vereinfachen.

Das Projekt *optes*, Optimierung der Selbststudiumsphase, wird im Rahmen des Qualitätspakts Lehre aus Mitteln des Bundesministeriums für Bildung und Forschung gefördert (Förderkennzeichen 01PL12012). www.optes.de

## Literatur

Bargel, T. (2015). *Studieneingangsphase und heterogene Studentenschaft - neue Angebote und ihr Nutzen. Befunde des 12. Studierendensurveys an Universitäten und Fachhochschulen.* Hefte zur Bildungs- und Hochschulforschung 83, Arbeitsgruppe Hochschulforschung.

BMBF Bundesministerium für Bildung und Forschung (2011) Qualitätspakt Lehre Pressemitteilung https://www.bmbf.de/de/qualitaetspakt-lehre-524.html

cosh cooperation schule:hochschule (2014). *Mindestanforderungskatalog Mathematik (2.0) der Hochschulen Baden-Württembergs für ein Studium von WiMINT-Fächern* http://www.mathematik-schule-hochschule.de/images/Aktuelles/pdf/MAKatalog_2_0.pdf

Daniel, M. & Wingerter, B. (2015). STACK – Ein neuer Fragetyp in der Mathematik, Tagungsband zum 2. HD-MINT Symposium, Nürnberg, 54–57.

Halm, L., Heubach, M., Mersch, A. & Wrenger, B. (2013). Zwei Seiten des Online-Lernens in mathematischen Grundlagenveranstaltungen: Unterstützung Lehrender und Betreuung Studierender im Selbststudium, *Tagungsband zum 1. HD MINT Symposium, Nürnberg*, 177–183.

Martinez, M. E. (1999). Cognition and the Question of Test Item Format. *Educational Psychologist*, *34* (4), 207–218.

Renkl, A. (1991). *Die Bedeutung der Aufgaben- und Rückmeldungsgestaltung für die Leistungsentwicklung im Fach Mathematik.* Dissertation, Universität Heidelberg.

Samoila, O., Heubach, M., Mersch, A. & Wrenger, B. (2016). Das ePortfolio und flankierende Maßnahmen des Verbundprojektes optes zur Unterstützung INT-Studierender in mathematischen Grundlagenveranstaltungen. In: A. Hoppenbrock et al. (Hrsg.) *Lehren und Lernen von Mathematik in der Studieneingangsphase. Herausforderungen und Lösungsansätze*. Berlin: Springer Spektrum, 423-434.

Sangwin, C. (2013). *Computer Aided Assessment of Mathematics Using Stack.* Oxford University Press.

Shavelson, R. J. et al. (2008). On the impact of curriculum-embedded formative assessment on learning: A collaboration between curriculum and assessment developers. *Applied measurement in education* (21), 295–314.

Winne, P. H. (2004). Students’ calibration of knowledge and learning processes: Implications for designing powerful software learning environments. *International Journal of Educational Research*, *41* (6), 466–488.

A.5 Derr, K.; Jeremias, X.V.; Schäfer, M. (2016). "(e)-bridging courses in mathematics: best practice reports from three universities" (Original title: Optimierung von E-Brückenkursen Mathematik: Beispiele von drei Hochschulen). In A. Hoppenbrock et al. (eds.). Lehren und Lernen von Mathematik in der Studieneingangsphase. Springer Spektrum, Berlin, pp. 115–129.

ISBN: 978-3-658-10261-6

# Optimierung von (E-)Brückenkursen Mathematik: Beispiele von drei Hochschulen

**8**

Katja Derr, Xenia Valeska Jeremias und Michael Schäfer

**Zusammenfassung**

An Hochschulen und Universitäten hat sich eine Vielzahl unterschiedlicher Ansätze für Mathematik-Brückenkurse entwickelt. Im vorliegenden Artikel werden die Konzepte von drei Hochschulen aus Baden-Württemberg, Brandenburg und Nordrhein-Westfalen vorgestellt, die alle einen umfangreichen E-Learning-Anteil einschließen. Dies wird als eine Optimierungsmöglichkeit von Angeboten zur Studienvorbereitung gesehen, da Online-Bestandteile eine höhere Flexibilität ermöglichen als klassische Präsenzkurse. Die Anpassung der Kurse auf die Teilnehmer/-innen z. B. durch diagnostische Eingangs- und Zwischentests gestattet unterschiedliche Lerngeschwindigkeiten, sodass ein individuelleres Aufarbeiten der fehlenden Vorkenntnisse möglich wird. Als unabdingbar für gute Blended-Learning-Angebote haben sich eine präzise Abstimmung der Selbstlernphasen und Präsenzveranstaltungen sowie entsprechend aufbereitete Materialien herausgestellt. Online-Selbsttests, die sowohl auf Seiten der Lernenden als auch für die Lehrenden Rückmeldungen über die Passgenauigkeit des Lehr-Lernverhaltens liefern, runden die Konzepte ab.

Katja Derr ✉
Duale Hochschule Baden-Württemberg, Mannheim, Mannheim, Deutschland
e-mail: katja.derr@dhbw-mannheim.de

Xenia Valeska Jeremias
Technische Hochschule Wildau, Zentrum für Qualitätsentwicklung, Wildau, Deutschland
e-mail: xenia.jeremias@th-wildau.de

Michael Schäfer
Hochschule Ruhr West, Mülheim an der Ruhr, Deutschland
e-mail: michael.schaefer@hs-ruhrwest.de



A. Hoppenbrock et al. (Hrsg.), *Lehren und Lernen von Mathematik in der Studieneingangsphase*, Konzepte und Studien zur Hochschuldidaktik und Lehrerbildung Mathematik, DOI 10.1007/978-3-658-10261-6_8

## 8.1 Einleitung

In den vergangenen Jahren hat das Interesse an technischen Studiengängen deutlich zugenommen; im Studienjahr 2011 stieg die Zahl der Studienanfänger/-innen in diesem Bereich sogar stärker an als in anderen Studienrichtungen. Ebenfalls deutlich gestiegen ist die Studienabbruchquote in MINT-Fächern. Während sie an Universitäten teilweise oberhalb von 50 % liegt, brechen an Fachhochschulen ungefähr 1/3 der Studierenden in MINT-Fächern ihr Studium ab (Heublein et al. 2012). Häufig genannte Motive für einen Abbruch des Studiums sind zu hohe Leistungsanforderungen bzw. nicht bestandene Zwischen- und Abschlussprüfungen (Heublein et al. 2010). Dabei ist eine wachsende Differenzierung der Schulabgänger/-innen in Bezug auf ihre Grundkenntnisse zu beobachten, insbesondere im Bereich der Mathematik. Für die Konzeption und Durchführung von Brückenkursen stellt die starke Heterogenität der angehenden Studierenden eine hohe Herausforderung dar.

Der vorliegende Artikel gibt einen Überblick über unterschiedliche Ansätze zur Gestaltung und Evaluation von online-gestützten Brückenkursen und liefert Anregungen und Tipps aus der Praxis zur Implementierung von E-Brückenkursen an kleinen bis mittleren Hochschulstandorten. Im letzten Abschnitt wird auf technische und didaktische Probleme und mögliche Verbesserungsmaßnahmen bei den beschriebenen Projekten hingewiesen.

Die DHBW Mannheim ist mit etwas mehr als 6000 Studierenden (davon 2000 an der Fakultät Technik) der zweitgrößte Standort der staatlichen Dualen Hochschule Baden-Württemberg. Studierende der DHBW sind während ihres Studiums bei einem Partnerunternehmen angestellt; die Theoriephasen an der Hochschule wechseln sich ab mit Praxisphasen im Unternehmen. Parallel zu den Anforderungen des ersten Semesters sind Defizite in Schulmathematik nur schwer abzubauen.

Die TH Wildau [FH] ist mit rund 4200 Studierenden die größte Fachhochschule Brandenburgs und bietet schwerpunktmäßig Studiengänge aus den Bereichen Ingenieurwesen und Wirtschaft (sowohl Vollzeit als auch berufsbegleitend) an. Mathematik ist dabei (mit einer Ausnahme) in allen Studiengängen enthalten.

Die Hochschule Ruhr West (HRW) ist eine im Jahr 2009 gegründete Hochschule in Nordrhein-Westfalen, die für 4000 bis 4500 Studierende ausgelegt ist und den Schwerpunkt auf MINT-Fächer legt.

Die in diesem Artikel vorgestellten Konzepte unterscheiden sich in ihrer Gewichtung der Online- und Präsenzanteile und der Adaptivität der Systeme. In Tab. 8.1 werden Gemeinsamkeiten und Unterschiede der drei Konzepte dargestellt. Das Konzept der DHBW Mannheim umfasst umfangreiche diagnostische Tests, auf deren Basis Lernempfehlungen mit Links zu Online-Lernmodulen ausgesprochen werden. Die TH Wildau [FH] setzt den Fokus auf innovative Aufgabenformate; die Besonderheit an der Hochschule Ruhr West ist das adaptive Konzept der Online- und Präsenzveranstaltungen.

Der Grad der Online-Anteile ist unterschiedlich hoch: In Mannheim wurde mit einem E-Learning-Programm begonnen, das erst im weiteren Projektverlauf durch Präsenzelemente erweitert wird, während in Wildau und an der HRW von vornherein ein Blended-Learning-Konzept verfolgt wird.





**Tab. 8.1** Übersicht über die in den Brückenkursen eingesetzten Maßnahmen

| | DHBW Mannheim | TH Wildau [FH] | HS Ruhr West |
|---|---|---|---|
| Diagnostischer Eingangstest | E-Assessment:<br>89 Items<br>10 math. Gebiete<br>Bearbeitungszeit 120 min<br>ab Juli (erstmalig 2011) | E-Assessment:<br>11 Items<br>10 math. Gebiete<br>Bearbeitungszeit 20 min<br>erstmalig 2013 | Paper & Pencil:<br>48 Items<br>14 math. Gebiete<br>Bearbeitungszeit 30 min<br>Digitalisiert über Optical Mark Recognition |
| Selbstlernphase | Online-Kursraum (Moodle):<br>Lernmodule zu 10 math. Gebieten als PDF-Skript/als interaktives Lernmodul<br>Übungsaufgaben für jedes Kapitel inklusive Musterlösungen<br>Abschlusstests für jedes Lernmodul | Online-Kursraum (Moodle):<br>18 Lernmodule u. a. mit ausführlichen Musterlösungen<br>Kurztests zu jedem Thema mit diff. Feedback<br>Steht auch im Semester zur Verfügung<br>Betreuung durch Tutoren (Mail, Forum, Skype) | Online-Kursraum (Moodle):<br>umfangreiche Lernmodule zu allen Bereichen der Mathematik ab 10-ter Klasse<br>> 100 Übungsaufgaben mit Lösungen<br>Kurztests zu jedem Thema mit Feedbackskala<br>Online-Betreuung via Mail und im Forum |
| Präsenzphase | Nur für TN mit FH-Reife: 5 Tage (vormittags Vorlesung, nachmittags Übung) | 5 Präsenztermine samstags (14-tägig), davon einer nur für Ingenieure | Coaching-Konzept auf Basis von Eingangstestergebnis: 1–3 Wochen (6 h/Tag) |
| Abschlusstest | E-Assessment:<br>zu Studienbeginn in PC-Räumen der HS<br>47 Items<br>10 math. Gebiete<br>Bearbeitungszeit: 60 min | Paper & Pencil (auf Wunsch der TN):<br>7 Fragen<br>8 math. Gebiete<br>Bearbeitungszeit: 45 min | Paper & Pencil:<br>Inhaltlich identisch mit Eingangstest<br>Bearbeitungszeit: 30 min |
| Evaluation | Feedback-Fragebogen<br>Testergebnisse „vorher/nachher"<br>Testergebnisse 2011/2012 | Feedback-Fragebogen<br>Testergebnisse | Effektmessung über T-Test abhängiger Stichproben<br>Formative Evaluation |
| $n$ (2012) | Gesamt: $n = 873$ (beide Tests: $n = 654$) | $n = 50$ (Pilotphase) | $n = 893$ |

## 8.2 Projektbeschreibung und Ergebnisse

Im Folgenden werden die in Tab. 8.1 aufgelisteten Bestandteile der Brückenkurse ausführlicher vorgestellt.

### 8.2.1 Diagnostischer Eingangstest

Das Bearbeiten von Aufgaben bzw. die Durchführung von Selbst-Assessments ist meist ein zentraler Bestandteil von E-Learning-Angeboten und bei Lernenden beliebt, wenn sie schnelles und aussagekräftiges Feedback vom System erhalten (z. B. Heidenreich 2009; Whitelock 2008). In der Literatur wird für diese Form des „lernprozessbegleitenden" Tests (Klieme et al. 2010) der Begriff des formativen Assessment verwendet, das – im Unterschied zum summativen Assessment – vor allem zur Selbstdiagnose und zum Einüben von erlernten Techniken und Verfahren dient (Black und William 1998).

Im Rahmen der vorgestellten Brückenkurse ist dementsprechend zu unterscheiden zwischen eher umfangreichen diagnostischen (Eingangs-)Tests, die eine erste Orientierung und Einschätzung der eigenen Kenntnisse liefern, sowie themenbezogenen Kurztests oder Übungsaufgaben zur Selbstkontrolle nach oder während der Bearbeitung einer Lerneinheit. Letztere werden im Abschnitt „Selbstlernphase" beschrieben.

Beim Umfang der Eingangstests wurden an den drei Standorten unterschiedliche Ansätze verfolgt. In Mannheim wurde ein sehr umfangreicher diagnostischer Test verwendet, der mittelfristig auch Aufschluss über die Entwicklung der Kenntnisse der Kohorten geben soll, während Wildau einen eher kurzen aktivierenden Test einsetzte. Mit 48 Items lag der Test der Hochschule Ruhr West im Mittelfeld. Welcher Variante der Vorzug gegeben wird, hängt von unterschiedlichen Faktoren ab, z. B. welches Spektrum der daran anschließende Vorkurs abdeckt, ob die Tests zu Hause oder vor Ort durchgeführt werden und welche Aussagen aus den Ergebnissen abgeleitet werden sollen. Angesichts der unterschiedlichen Konzeption sind die Ergebnisse in den Eingangstests nur bedingt vergleichbar, dennoch lassen sich einige Parallelen ziehen.

Die Testergebnisse waren an allen drei Hochschulstandorten sehr heterogen, mit teilweise erheblichen Wissenslücken in den Themengebieten Geometrie und Trigonometrie sowie deutlichen Schwierigkeiten bei komplexeren Termumformungen und Funktionen. Selbst einfache Bruchrechenaufgaben stellen manche Teilnehmer/-innen vor Probleme, und das Themengebiet Vektorrechnung kann bei einer großen Anzahl der Studienanfänger/-innen offenbar nicht mehr als bekannt vorausgesetzt werden. Angesichts der großen Unterschiede der Schulsysteme und Curricula in Deutschland überrascht dieses Ergebnis nicht und ist in Übereinstimmung mit anderen Studien (z. B. Bescherer 2003; Biehler et al. 2012; Polaczek und Henn 2008; Schwenk und Berger 2006).

Sehr deutlich zeigte sich die starke Streuung der Ergebnisse an der DHBW Mannheim, aufgrund ihrer Lage Einzugsgebiet für Schulabsolventen aus mehreren Bundesländern. Der auf zwei Stunden angesetzte Eingangstest basiert auf dem Lehrplan der Mittel- und





Oberstufe in Baden-Württemberg und deckt zehn mathematische Grundlagenthemen ab. Neben grundlegenden Rechentechniken wie Termumformungen oder Auflösen von Gleichungen wurden Fragen aus den Bereichen Geometrie, Trigonometrie, Logik sowie Vektorrechnung gestellt.

In beiden Jahren erreichten die Teilnehmer durchschnittlich weniger als die Hälfte der Punktzahl, wobei die Ergebnisse im Jahr 2012 schwächer waren als 2011. Dabei hatte die Schul-Mathematiknote den stärksten Einfluss auf das Testergebnis, wobei auch in der Gruppe mit sehr guten Noten die Ergebnisse stark streuten. Als weiterer starker Faktor ist die Art der Hochschulzugangsberechtigung zu nennen: Absolventen von Gymnasien erzielten deutlich höhere Mittelwerte als die von Fachgymnasien, die wiederum besser abschnitten als Studienanfänger/-innen mit Fachhochschulreife. Für weitere Faktoren wie Alter, Geschlecht, Bundesland oder gewählter Studiengang konnte kein statistisch signifikanter Zusammenhang mit den Testergebnissen festgestellt werden.

Der Online-Eingangstest an der TH Wildau [FH] (erstmalig 2013 durchgeführt) bestand aus elf Fragen, die mathematische Gebiete von Prozenten bis Integralen abdeckten, für die ein Zeitlimit von 20 Minuten gesetzt wurde. Auffällig war hier, wie auch an der DHBW, dass in einem Drittel der Fälle die Zeit nicht ausreichte. Durchschnittlich wurden etwa 30 % der Punkte erreicht, wobei die Spannweite von 0 bis 84 % reichte. Aufgaben zu den Themen Prozentrechnung sowie lineare Funktionen wurden dabei zu etwa 75 % richtig beantwortet; bei Ableitungen und Integralen lag die „Richtig-Quote" bei 10 bis 15 %. Offensichtlich eingabebedingte Fehler wurden nachträglich bereinigt. Da sich zeigte, dass die Probleme sowohl bei angehenden Ingenieuren als auch bei angehenden Wirtschaft-

TEST MATHEMATIK

HRW HOCHSCHULE RUHR WEST UNIVERSITY OF APPLIED SCIENCES

I. Elementare Algebra

**Vereinfachen Sie, falls möglich, folgende Ausdrücke:**

a) $\frac{2}{3}+\frac{3}{4}=$ $\frac{3}{2}-\frac{4}{3}=$ ☐☐

$\frac{9}{5}\cdot\frac{2}{3}=$ ☐

b) $a^4\cdot a^5=$ ☐

$\sqrt{a}\cdot\sqrt{b}=$ ☐

$\sqrt[5]{b}\cdot\sqrt{b}=$ ☐

**Abb. 8.1** Ausschnitt aus dem Eingangstest der Hochschule Ruhr West lern häufig bereits in der Mittelstufenmathematik liegen, wurde der Brückenkurs für beide Gruppen gemeinsam angeboten.

Im Eingangstest der Hochschule Ruhr West, an dem im WS 2012/13 $n = 893$ Studierende teilnahmen, wurden hauptsächlich einfache Rechentechniken untersucht. Angefangen mit der Addition, Subtraktion und Multiplikation (s. Abb. 8.1) von je zwei Brüchen (Fehlerquote > 20 %), über das Rechnen mit Potenzen und Wurzeln (Fehlerquote > 30 %), die grafische Darstellung einfacher Funktionen (Fehlerquote > 50 %) bis zu Grundableitungen und Grundintegralen sind die Ergebnisse sehr ernüchternd (Schäfer 2013). Festzustellen ist, dass die Ergebnisse ein verstärktes Engagement in der Studieneingangsphase nahelegen, um die Studienerfolgsquote zu verbessern.

## 8.2.2 Selbstlernphase

In Bezug auf Nutzungshäufigkeit und -intensität der Lernmaterialien konnte wiederum eine hohe Heterogenität festgestellt werden, allerdings mit leichten Unterschieden zwischen den Standorten.

In Mannheim wurden Lernmodule zu den zehn Grundlagenthemen entwickelt (Abb. 8.2). Nach Testdurchführung erhielten die Teilnehmer/-innen eine E-Mail mit einer Übersicht über ihre Ergebnisse plus, falls diese in einer oder mehreren Kategorien unter einer festgesetzten Grenze lagen, Lernempfehlungen und Links zu den entsprechenden Lernmodulen. Diese wurden jeweils ab Juli bereitgestellt und konnten als PDF-Skript

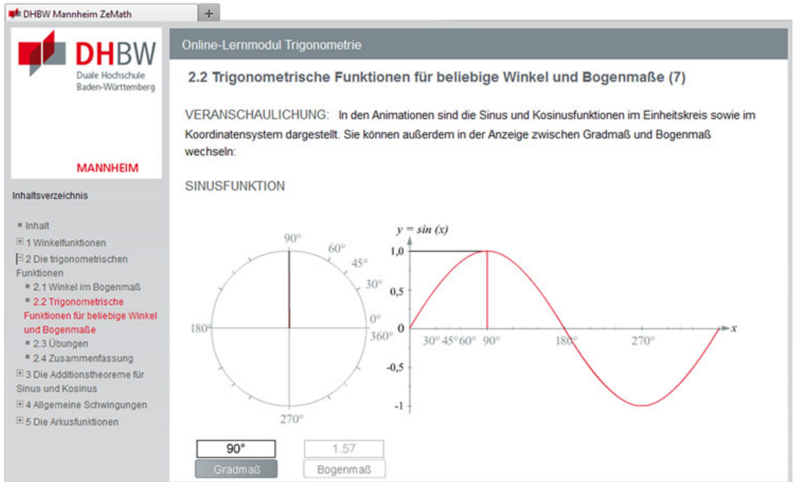



**Abb. 8.2** Ausschnitt aus dem Lernmodul Trigonometrie, DHBW Mannheim





heruntergeladen oder alternativ als Online-Lernmodul bearbeitet werden (2012 waren vier der zehn Lernmodule in der interaktiven Version verfügbar). Die Module enthielten neben Erklärungen zu den mathematischen Inhalten immer wieder Übungsaufgaben sowie einen themenbezogenen Schlusstest.

In den Jahren 2011 und 2012 gaben mehr als 80 % der Eingangstest-Teilnehmer/-innen an, ein oder mehrere Lernmodule bearbeitet zu haben. Häufigkeit und Dauer der Lernaktivitäten unterschieden sich allerdings erheblich, auch ließ die Aktivität insgesamt nach der Bearbeitung von zwei bis drei Lernmodulen teilweise recht deutlich nach. Als Begründung gaben Teilnehmer/-innen vor allem mangelnde Zeit, aber auch Motivationsprobleme und Verständnisschwierigkeiten an.

Ein interessantes Phänomen zeigte sich in Bezug auf die Nutzung des E-Learning-Angebots: Während eine Gruppe die interaktiven Module klar bevorzugte und bemängelte, dass nicht alle Lerninhalte in dieser Form zur Verfügung standen, war eine zweite Gruppe dem Lernen am Computer gegenüber generell skeptisch eingestellt und nutzte ausschließlich ausgedruckte PDFs. Eine kleinere dritte Gruppe nutzte beides.

Kern des Moodle-Kursraums in Wildau sind Lernmodule mit vielen Aufgaben, Erklärungen und ausführlichen, kommentierten Musterlösungen zu den Themen, die im Laufe des Brückenkurses besprochen werden (Grundrechenarten bis Integralrechnung). Einige Kapitel bzw. Teile von Kapiteln sind als Selbstlerneinheiten konzipiert. Zu jedem Thema gibt es einen kurzen, interaktiven Selbsttest, der jeweils fünf zufällig ausgewählte Fragen umfasst. Die Zufallsauswahl und die Größe des dahinter liegenden Fragenpools gewährleisten, dass die Teilnehmenden auch bei mehrmaliger Durchführung sinnvolle Erkenntnisse zu ihrem Lernstand erhalten. Zudem wird darauf geachtet, dass aktivierende, kompetenzorientierte Fragen Verwendung finden, also fast keine MC-Fragen. Auch wenn in erster Linie auf eher einfache Rechenkompetenzen abgezielt wird, war/ist es nötig, neue Fragetypen zu entwickeln. Wert wird zudem speziell auf ein differenziertes Feedback sowohl der Fragen als auch der Assessments gelegt, sodass z. B. nach Durchführung des Einstiegstests erkennbar wird, welche Lernmodule bearbeitet werden sollten.

Auch in Wildau nahm das Engagement, sich in den Online-Phasen mit den Brückenkursinhalten zu beschäftigen, im Verlauf des Kurses ab. Allerdings blieb der Kursraum nach Abschluss der Blended-Learning-Phase auf der Lernplattform aktiv, sodass auch im Semester darauf zugegriffen werden konnte. Auch wenn es bekannterweise zwischen den Online-Materialien und den Semesterinhalten in einigen Studiengängen Überschneidungen gab, war 2012 eine erstaunlich hohe Aktivität in diesem Moodle-Kursraum durch das ganze Semester hinweg bis in die Prüfungszeit hinein zu beobachten. Für die Betreuung der Teilnehmer/-innen in den Selbstlernphasen hat sich die hochschulweit dauerhaft zur Verfügung stehende E-Mailadresse tutor.mathe@th-wildau.de bewährt. Eingehende Fragen werden von Projekttutoren, die auch in den Brückenkurs eingebunden waren, innerhalb von 24 Stunden beantwortet. Dieses Angebot wird zwar unterschiedlich stark, aber insgesamt gut genutzt (s. Abb. 8.3).

An der Hochschule Ruhr West steht die Adaptierung der Materialien auf Grund des Vorwissens der Studierenden im Vordergrund, um so die Passgenauigkeit zu verbessern

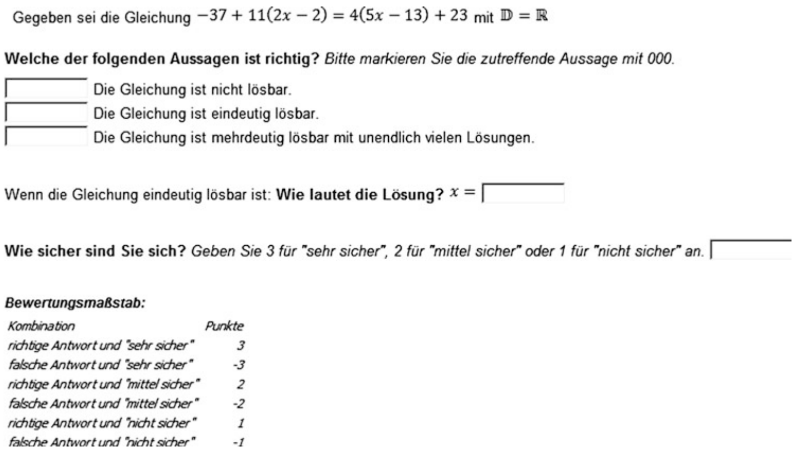



**Abb. 8.3** Beispiel für eine E-Test-Aufgabe entwickelt an der TH Wildau [FH]

und die Studierenden weder zu langweilen noch zu überfordern (Schulmeister 2007). Gleichzeitig wird versucht, durch kurzfristiges optisches Feedback Anreize zu setzen, um die Verweildauer im Kurs zu erhöhen. In Abb. 8.4 ist eins von dreizehn Lernelementen dargestellt. Die Studierende hat in diesem Fall, auf Grund des Eingangstests ermittelt, sehr gute Kenntnisse („Daumen hoch") in diesem Themenbereich, wobei sie bei den Selbsttestaufgaben nur jeweils 3 von 5 „Sternchen" bekommen, also nur mittelmäßig in der Selbstüberprüfung abgeschnitten hat.

Neben den inhaltlichen Elementen werden u. a. Videocasts eingesetzt, um gerade auch Studierende, denen die Metakompetenzen zum selbstgesteuerten Lernen fehlen, zu zielführenden Handlungen mit schnellen Erfolgserlebnissen zu führen.

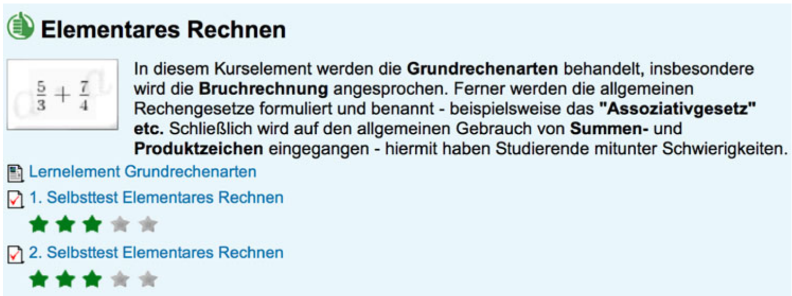



**Abb. 8.4** Einzelnes Lernelement mit zugehörigen Selbsttests aus dem Brückenkurs der HRW





Insgesamt schnellt die Online-Beteiligung nach der ersten Informationsmail mit den persönlichen Zugängen nach oben, wobei die Aktivitäten mit dem Beginn der Präsenzkurse (6 Stunden pro Tag) auf die Wochenenden beschränkt bleiben und mit dem Start der Semesterveranstaltungen nahezu eingestellt werden. Eine verstärkte Aktivität ist dann kurz vor der ersten Mathematik-Klausur zu beobachten.

### 8.2.3 Präsenzphase

Das Mannheimer Konzept sah ursprünglich keine Präsenzphase vor, da der Großteil der Studienanfänger/-innen in den Sommermonaten Vorpraktika besucht und nicht vor Ort sein kann. Es zeigte sich allerdings schon bei einem ersten Testdurchlauf 2010, dass vor allem Studienanfänger/-innen mit Fachhochschulreife wenig von den Selbstlernangeboten profitierten. In den Jahren 2011 und 2012 wurde zusätzlich ein einwöchiges Präsenzseminar für sie angeboten. Dieses wurde zwar gut angenommen und sehr positiv evaluiert, führte aber dazu, dass die Selbstlernangebote weniger intensiv genutzt wurde. Trotz dieser Effekte soll das Präsenzangebot im Projektverlauf für weitere Teilnehmergruppen geöffnet werden, um Lernende mit einer Präferenz für Kontaktstudium besser anzusprechen.

Die Präsenztermine sind integraler Bestandteil des Brückenkurses an der TH Wildau [FH]. Diese müssen am Wochenende stattfinden, da der Kurs, um ausreichend Zeit für die Bearbeitung der wichtigsten Themen zu haben, bereits *vor* Ende des Bewerbungszeitraumes beginnt und viele Teilnehmer/-innen zu dieser Zeit unter der Woche noch andere Verpflichtungen haben. Außer am ersten Präsenztermin, der drei Vorlesungen umfasst, werden die Teilnehmenden im ersten Block für eine Übung in drei Kleingruppen eingeteilt, in denen Fragen aus der Online-Phase aufgegriffen und diskutiert werden. So ergibt sich eine gute Verzahnung zwischen Online- und Präsenzanteilen. Es schließen sich jeweils zwei Vorlesungen an. Die Vorlesungen am letzten Präsenztermin sind ausschließlich für angehende Ingenieure vorgesehen, sodass hierüber nötige Differenzierungen zwischen den verschiedenen Studienrichtungen vorgenommen werden können.

Die Präsenz an der Hochschule Ruhr West wird auf Grund der Eingangsfähigkeiten der Studierenden adaptiert. Hierzu werden drei Leistungsgruppen ermittelt, die unterschiedlich lange Präsenzphasen besuchen können. So hat die leistungsschwächste Gruppe drei Wochen an jeweils fünf Tagen je sechs Stunden Unterricht, während die leistungsstärkste Gruppe nur eine Woche Unterricht hat.

Aus psychologischen Gründen werden die Gruppen jeweils mit der nächstbesseren Leistungsgruppe aufgestockt. So beginnen die leistungsschwachen Studierenden in zwanzig Kleingruppen mit weniger als zehn Studierenden, um nach einer Woche durch Hinzunahme der nächsten Studierenden auf 20 anzuwachsen. In der letzten Woche ergibt sich dann eine Gruppengröße von maximal 35 Studierenden. In den einzelnen Wochen wird jeweils mit dem gleichen Inhalt begonnen, nur eine höhere Unterrichtsgeschwindigkeit genutzt. Hierdurch ergibt sich für die einen eine Wiederholung, an der diese sich aktiv beteiligen können, für die anderen, die neu hinzugekommenen sind, ist die Lerngeschwindigkeit passgenauer.

Insgesamt führt dieses Vorgehen zu einer Zunahme der Fähigkeiten aller Studierenden, bei gleichzeitiger Homogenisierung der Leistungsunterschiede.

### 8.2.4 Evaluation

Hauptziel der Evaluation in Mannheim war die Untersuchung der Wirksamkeit der Maßnahme, zusätzlich sollte im Hinblick auf Verbesserung und Weiterentwicklung die Qualität der diagnostischen Tests analysiert werden. Ein weiteres Ziel war der Erkenntniszuwachs in Bezug auf Zusammenhänge zwischen Testergebnissen und persönlichen Faktoren wie mathematischem Vorwissen, Einstellung zur Mathematik, Art und Umfang der Nutzung des Lernangebots.

Zur Messung der Wirksamkeit der Studienvorbereitung wurde ein Vergleich zwischen Eingangs- und Kontrolltestergebnissen unternommen. Die Studierenden, die an beiden Tests teilgenommen haben (2011 $n = 506$; 2012 $n = 654$) erzielten im Kontrolltest insgesamt bessere Mittelwerte als im Eingangstest, und schnitten auch deutlich besser ab, als die Teilnehmer/-innen, die nur den Kontrolltest durchgeführt und nicht an der Studienvorbereitung teilgenommen hatten.

Ein signifikanter Zusammenhang zwischen Lernmodulbearbeitung und Lernerfolg ließ sich allerdings nicht nachweisen, da auch bei dieser Auswertung die Daten stark streuten (s. Abb. 8.5). Die stärksten Verbesserungen ließen sich für die Gruppe der Teilnehmer/-innen mit Abitur und/oder guten Mathematiknoten bei weniger gutem Eingangstestergebnis feststellen. Diese erhielten eine entsprechend hohe Anzahl an Lernempfehlungen und konnten sich durch die Beschäftigung mit den Lernmodulen deutlich steigern. Teilnehmer/-innen ohne Abitur konnten sich durch Teilnahme an der Selbstlernphase zwar auch verbessern, der Abstand zu den Abiturient/-innen konnte allerdings nur in Einzelfällen geschlossen werden.

Daten zum Nutzerverhalten und zur Zufriedenheit mit dem Angebot wurden über einen Evaluationsfragebogen erfasst; zur Hinterfragung bzw. Bestätigung der quantitativen Daten wurden im Jahr 2012 zusätzlich Gruppeninterviews mit insgesamt 13 Studienanfänger/-innen der Fakultät Technik durchgeführt. Während die Akzeptanz des Lernangebots hoch war und die Usability überwiegend als gut bis sehr gut bezeichnet wurde, wurde der Schwierigkeitsgrad sowohl der diagnostischen Tests als auch der Lernmodule unterschiedlich eingeschätzt. So wurde der Eingangstests von etwa 50 % der Teilnehmer/-innen als „schwer" bzw. „sehr schwer" bezeichnet.

Bei der Evaluation in Wildau überraschte die Tatsache, dass auch die Teilnehmer/-innen mit Abitur (GK und LK Mathematik) größtenteils angaben, dass der Brückenkurs für sie „nicht unbedingt notwendig, aber hilfreich" bzw. sogar „unbedingt notwendig" gewesen war. Ein besonderer Schwerpunkt der Evaluation lag auf der Abstimmung zwischen Online-Phasen und Präsenzterminen, da das erste Mal ein Brückenkurs in dieser Blended-Learning-Form angeboten wurde. Im Gegensatz zu den herkömmlichen Brückenkursen, die übereinstimmend als zu kurz und zu komprimiert beurteilt wurden, erfuhr diese Orga-





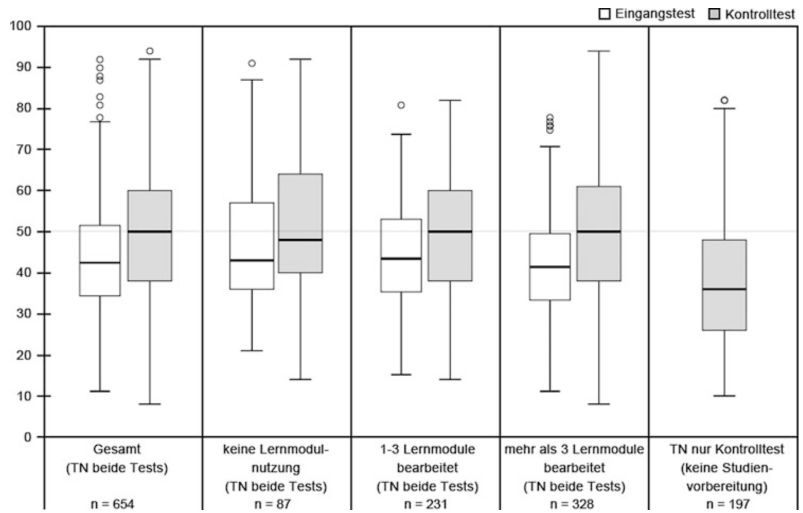



**Abb. 8.5** Testergebnisse DHBW Mannheim Eingangstest und Kontrolltest 2012. (Vergleich Teilnehmer an beiden Tests/nach Lernmodulbearbeitung*/Teilnehmer nur Kontrolltest) (*missing: $n = 8$)

nisationsform hohe Zustimmung. Da 2012 kein Eingangstest durchgeführt wurde, können keine Aussagen über eine mögliche Verbesserung der Teilnehmer/-innen getroffen werden.

An der Hochschule Ruhr West ergab eine formative Evaluation im Dezember 2012 mit einem Rücklauf von $n = 94$ eine hohe individuelle Passgenauigkeit der Anforderungen in den Vorkursen und eine positive Einschätzung der adaptiven Maßnahmen auf den persönlichen Lernerfolg. Eine summative Evaluation im Oktober 2012 ergab einen großen Lernzuwachs der Studierenden durch den Einsatz des Systems. In einem *t*-Test abhängiger Stichproben wurde ein starker Effekt ($d = 1{,}83$) nachgewiesen. Die erreichte mittlere Punktzahl im Ausgangstest hat sich im Vergleich zum Eingangstest mehr als verdoppelt (Eingangstest: $M = 13{,}70$; $SD = 8{,}82$; $n = 132$, Ausgangstest: $M = 28{,}48$; $SD = 7{,}31$; $n = 132$) und die Leistungsunterschiede zwischen den Studierenden haben sich angeglichen.

## 8.3 Diskussion/Ausblick

Angesichts der hohen Heterogenität innerhalb der Zielgruppe ist es schwierig, eindeutige Empfehlungen zur Optimierung von Brückenkursen abzuleiten. Das Ziel sollte sein, möglichst breite und adaptive Angebote zu entwickeln, die für möglichst viele

Studienanfänger/-innen passende Elemente bereithalten. Dies gilt nicht nur im Hinblick auf die fachliche Entwicklung der Teilnehmer/-innen, wie auch die Erfahrungen an der Hochschule Ruhr West zeigen: Die Anpassung der Online- und Offline-Angebote an die Vorkenntnisse der Studierenden führte hier zu einem guten Lernerfolg *und* hoher Zufriedenheit bei allen Studierenden.

Die vorgestellten Ansätze der drei Hochschulen zeigen verschiedene technische und didaktische Aspekte, die im Rahmen der Optimierung von Brückenkursangeboten Beachtung finden sollten, von denen hier die bedeutendsten noch einmal herausgegriffen und diskutiert werden sollen.

E-Learning-Module sind grundsätzlich gut geeignet, um heterogene Zielgruppen zu adressieren, da die Zeiteinteilung – anders als in klassischen Präsenzkursen – flexibel ist. Dies stellt einen erheblichen Mehrwert gegenüber anderen Angeboten dar, vorausgesetzt die E-Learning-Materialien sind qualitativ hochwertig. Mehr noch als im Präsenzbereich sind hier gut nachvollziehbare Strukturen und eine durchdachte Gestaltung der Inhalte vonnöten. Die Arbeit im Selbststudium erfordert außerdem konsistente Betreuungs- sowie Blended-Learning-Konzepte, um die Motivation z. B. durch klare Kommunikationsmöglichkeiten und individuelles Feedback in Zwischentests aufrecht zu erhalten (Niegemann et al. 2004). Neben Studierenden, die aufgrund geringerer Vorkenntnisse mehr Zeit für die Erarbeitung der relevanten Inhalte brauchen, wird es immer Studierende geben, die zwar einen Brückenkurs benötigt hätten, ihn aber nicht besucht haben (Polaczek und Henn 2008). E-Brückenkurse bieten die Möglichkeit, fehlende Vorkenntnisse während des ersten Semesters nachzuarbeiten. Das hilft auch den Dozenten, die so diesen Teil der Mathematik nicht behandeln müssen, und damit der ganzen Seminargruppe, weil mehr Zeit für die eigentlichen Studieninhalte bleibt.

Grundsätzlich ist bei allen Optimierungen und Gestaltungen von Online-Materialien darauf zu achten, dass das (technische) Medium zum zu vermittelnden Inhalt und zu den Lerngegebenheiten passt und dass zwischen den verschiedenen Angebotsteilen eine gute Verzahnung, die auf die Bedürfnisse der Zielgruppe ausgerichtet ist, hergestellt wird. Das reine „Verfügbarmachen“ von Materialien auf einer Lernplattform reicht nicht aus (Kerres et al. 2009). Diese Verzahnung betrifft im Brückenkursbereich insbesondere die Abstimmung der Lehrinhalte mit den Studieninhalten sowie mit den Rahmenplänen der Schulen, wie es z. B. in der cosh-Gruppe in Baden-Württemberg geschieht. Nicht zu vernachlässigen ist dabei, dass es verhältnismäßig ressourcenintensiv ist, einen Brückenkurs auf diese Weise umzugestalten. Es ist weder von Honorarkräften noch von „normal“ in die Hochschullehre eingebundenen Lehrkräften nebenbei zu bewältigen.

Die angebotenen E-Tests nützen den (angehenden) Studierenden bei der realistischen Selbsteinschätzung ihrer mathematischen Fähigkeiten. Dies bietet Optimierungsmöglichkeiten in doppelter Hinsicht: Zum einen können die Brückenkurs-Teilnehmer/-innen ihre individuellen Lernaktivitäten anpassen. Zum anderen erhält der/die Lehrende eine differenzierte Rückmeldung über die verschiedenen Lernstände und kann ggf. Themenauswahl und Schwerpunktsetzung an diese angleichen. Werden E-Tests zu diesem Zweck eingesetzt, ist darauf zu achten, dass sie nicht den Charakter einer Prüfung haben, sondern als





Hilfestellung im Lernprozess gesehen werden mit dem Ziel, die geeigneten Rahmenbedingungen für jede/n einzelne/n Teilnehmer/-in zu schaffen. Sowohl an der DHBW als auch an der TH Wildau [FH] zeigte sich in diesem Zusammenhang, dass dem Aspekt der Anonymität eine besondere Bedeutung zukommt. Immer wieder wurde die Befürchtung geäußert, dass schlechte Ergebnisse negative Auswirkungen auf die Bewerbung oder zukünftige Lehrveranstaltungen haben könnten. Es ist daher deutlich zu machen, dass sowohl die Testergebnisse als auch die Aktivität auf der Lernplattform zu keinem Zeitpunkt an Dozenten, das Immatrikulationsamt oder Arbeitgeber/Ausbildungsunternehmen weitergegeben werden, sondern ausschließlich für die Gestaltung des Lernweges genutzt werden.

Vorstellbar zur weiteren Optimierung der Angebote ist, die Tests in Selbstlernphasen als Selektionsmechanismus einzusetzen, indem z. B. bestimmte Kapitel erst freigeschaltet werden, wenn andere Kapitel, die zum Verständnis benötigt werden, erfolgreich absolviert wurden. Dies kann Frustrationen infolge von Überforderung bei den Teilnehmer/-innen vorbeugen (Handke und Schäfer 2012).

Bei der Entwicklung von E-Assessments ist die Eingabe von Formeln nach wie vor schwierig umzusetzen (Craven 2009). Auch das Abprüfen von Lösungswegen ist nicht bzw. nur schlecht möglich. Diese Einschränkung relativiert sich ein wenig, wenn man berücksichtigt, dass auch im klassischen Paper & Pencil-Tests, die zu Beginn von Brückenkursen geschrieben werden, häufig nur die Ergebnisse kontrolliert werden, weil dies bei der Masse der Teilnehmenden nicht anders möglich ist. Die Frage „E-Assessment oder Paper & Pencil“ ist grundsätzlich nicht entscheidend für die Qualität und Aussagekraft eines Tests, sondern allein seine didaktische Gestaltung als solche (Handke und Schäfer 2012). Zu berücksichtigen ist auch, dass es sich bei den Themen, die im Rahmen des Brückenkurses behandelt und abgefragt werden, um Grundlagen handelt, die für ein erfolgreiches Absolvieren der Mathematiklehrveranstaltungen im Studium absolut sicher beherrscht werden müssen. Es sind hierbei keine kreativen Rechenwege gefragt, sondern das sichere Anwenden von Lösungsroutinen. Die entsprechende Gestaltung vorausgesetzt kann die Prüfung solcher Fähigkeiten bereits mithilfe von Multiple-Choice-Fragen gelingen (Kastner und Stangl 2011). Vielfach ist aber eine andere Konzeption von Testfragen erforderlich, vor allem wenn stärker prozedurales Wissen in den Mittelpunkt des Assessments rückt. Generell macht der heutige Stand der Computerprogramme dies möglich (z. B. Sangwin und Badger 2010). Auch hier ist der Aufwand einer solchen Implementierung in Bezug auf technische und personelle Ressourcen allerdings nicht zu unterschätzen.

Wesentlich ist die Möglichkeit des manuellen Nachkorrigierens der Ergebnisse, z. B. um eventuelle Eingabefehler, die bei Online-Tests fast zwangsläufig auftreten, zu bereinigen. Dies ist insbesondere bei Assessments der Fall, die sich nicht auf MC-Fragen beschränken. Die grundsätzlich positive Einstellung zu E-Assessments bei Studierenden (z. B. Heidenreich 2009; Whitelock 2008) sollte nicht durch Fehl-Empfehlungen infolge von Eingabefehlern gefährdet werden. Auch die Akzeptanz von Online-Tests bei Lehrenden kann dadurch gesteigert werden, weil ihnen und nicht der Technik die endgültige Entscheidung über die Testergebnisse überlassen bleibt (Handke und Schäfer 2012). Allein die erhöhte Sichtbarkeit von E-Assessments, die durch die Brückenkurstests gegeben ist, wirkt in diese Richtung. An der TH Wildau [FH] ist es seitdem schon vermehrt zu Anfragen für weitere E-Tests gekommen, z. B. als Eignungstests für Studieninteressierte, die anders (noch) nicht erreicht werden können, sodass sich hier strukturelle Auswirkungen auf ganz andere Hochschulbereiche ergeben haben.

Die innovative Form der Brückenkurse verlangt, dass immer wieder kritisch geprüft wird, ob allen Anforderungen Rechnung getragen wird. So hat beispielsweise die DHBW auf Schwierigkeiten im ersten Jahr reagiert und Präsenzanteile wieder eingeführt, da diese offensichtlich benötigt wurden; auch wurde das Design der diagnostischen Tests basierend auf den Ergebnissen des Vorjahres optimiert. In Wildau wurden für den zweiten Jahrgang die Themen angepasst, um die Bedürfnisse der technischen Studiengänge stärker zu berücksichtigen. In den Online-Kurs der HRW wurden nachträglich motivierende Videocasts eingebunden, um den Durchhaltewillen der Teilnehmer/-innen zu stärken. Obwohl jede Änderung darauf ausgerichtet ist, die Brückenkursangebote unter den gegebenen Bedingungen zu optimieren, wird dieser Prozess nie wirklich zu einem Ende kommen, da auf der einen Seite die Entwicklungen im E-Learning-Bereich immer wieder neue Möglichkeiten eröffnen werden. Auf der anderen Seite sind die Anpassungen vorwiegend durch die Inhomogenität in der Gruppe der Studienanfänger/-innen bedingt. Verstärken sich diese Tendenzen, was durch die Öffnung der Hochschule für alternative Bildungswege zu erwarten ist, müssen sich auch die Bemühungen der Hochschulen, passende Angebote zu schaffen, erhöhen.

Bei Interesse können Zugänge zu den Tests und Lernmaterialien erstellt werden. Für einen Zugang zur Lernplattform der DHBW Mannheim schicken Sie bitte eine formlose E-Mail an zemath@dhbw-mannheim.de, weitere Informationen erhalten Sie unter http://www.zemath.dhbw-mannheim.de. Für einen Zugang zu den Tests und Lernmaterialien der TH Wildau [FH] senden Sie bitte eine formlose E-Mail an xenia.jeremias@th-wildau.de.

## Literatur


Bescherer, C. (2003). *Selbsteinschätzung der mathematischen Studierfähigkeit von Studienanfängerinnen und -anfängern*. Dissertation, Pädagogische Hochschule Ludwigsburg, Ludwigsburg.

Biehler, R., Fischer, P., Hochmuth, R., & Wassong, T. (2012). Designing and evaluating blended learning bridging courses in mathematics. In M. Pytlak, T. Rowland, & E. Swoboda (Hrsg.), *Proceedings of the Seventh Congress of the European Society for Research in Mathematics Education* (S. 1971–1980). Rzeszów, Polen: University of Rzeszów.

Black, P., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education*, *5*(1), 7–74.

Craven, P. (2009). *History and Challenges of e-assessment: The ‚Cambridge Approach' perspective – e-assessment research and development 1989 to 2009*. Cambridge: Cambridge University Press.

Handke, J., & Schäfer, A. M. (2012). *E-Learning, E-Teaching und E-Assessment in der Hochschullehre: Eine Anleitung*. München: Oldenbourg.







Heidenreich, S. (2009). *Pädagogische Anforderungen an das Lernhandeln im E-Learning. Dimensionen von Selbstlernkompetenz*. Medienpädagogik und Mediendidaktik, Bd. 16. Hamburg: Verlag Dr. Kovač.

Heublein, U., Hutzsch, C., Schreiber, J., Sommer, D., & Besuch, G. (2010). *Ursachen des Studienabbruchs in Bachelor- und in herkömmlichen Studiengängen – Ergebnisse einer bundesweiten Befragung von Exmatrikulierten des Studienjahres 2007/08*. Hannover: HIS.

Heublein, U., Richter, J., Schmelzer, R., & Sommer, D. (2012). *Die Entwicklung der Schwund- und Studienabbruchquoten an den deutschen Hochschulen – Statistische Berechnungen auf der Basis des Absolventenjahrgangs 2010*. Hannover: HIS.

Kastner, M., & Stangl, B. (2011). Multiple-Choice and Constructed Response Tests: Do Test Format and Scoring matter? *Procedia – Social and Behavioral Sciences*, *12*, 263–273.

Kerres, M., Ojstersek, N., & Stratmann, J. (2009). Didaktische Konzeption von Angeboten des Online-Lernens. In L. J. Issing, & P. Klimsa (Hrsg.), *Online-Lernen: Handbuch für Wissenschaft und Praxis* (S. 263–272). München: Oldenbourg.

Klieme, E., Bürgermeister, A., Harks, B., Blum, W., Leiß, D., & Rakoczy, K. (2010). Leistungsbeurteilung und Kompetenzmodellierung im Mathematikunterricht. Projekt Co2CA. *Zeitschrift für Pädagogik*, *56*(Beiheft), 64–74.

Niegemann, H., Hessel, S., Hochschied-Mauel, D., Aslanski, K., Deimann, M., & Kreuzberger, G. (2004). *Kompendium E-Learning*. Berlin: Springer.

Polaczek, C., & Henn, G. (2008). *Vergleichende Auswertung des Mathematik-Eingangstests*. Aachen: FH Aachen.

Sangwin, C. J., & Badger, M. (2010). Core Skills in Entry Level Mathematics. http://web.mat.bham.ac.uk/C.J.Sangwin/projects/2010STEM/CoreSkills2.pdf. Zugegriffen: 23. August 2013

Schäfer, M. (2013). *Knowledge Controlled Mathematical Coaching – Strategies and Results of a Personalized Blended Learning Approach* 5th International Conference on Computer Supported Education (CSEDU), 2013, Mai 06–08. (S. 484–488). Aachen: RWTH Aachen.

Schulmeister, R. (2007). *Grundlagen hypermedialer Lernsysteme: Theorie – Didaktik – Design* (4. Aufl.). München: Oldenbourg.

Schwenk, A., & Berger, M. (2006). Zwischen Wunsch und Wirklichkeit: Was können unsere Studienanfänger? *Die Neue Hochschule*, *2*, 36–40.

Whitelock, D. (2008). Accelerating the assessment agenda: thinking outside the black box. In F. Scheuermann, & A. G. Pereira (Hrsg.), *Towards a Research Agenda on Computer-Based Assessment – Challenges and Needs for European Educational Measurement* (S. 15–21). Luxembourg: Office for Official Publications of the European Communities.


katja.derr@dhbw-mannheim.de

A.6 Derr, K.; Hübl, R.; Ahmed, M.Z. (2015). “Using test data for successive refinement of an online pre-course in mathematics”. Proceedings 14th European Conference on e-Learning ECEL 2015, 29-30 October, Hatfield, pp. 173-180.

ISBN: 978-1-910810-70-5

http://www.academic-bookshop.com/ourshop/prod_4128381-ECEL-2015-14th-European-Conference-on-eLearning-Hatfield-UK-ISBN-9781910810705-ISSN-20488637.html

# Using Test Data for Successive Refinement of an Online Pre-Course in Mathematics

**Katja Derr[1], Reinhold Hübl[1] and Mohammed Zaki Ahmed[2]**
**[1]Baden-Wuerttemberg Cooperative State University Mannheim, Germany**
**[2]Plymouth University, UK**
katja.derr@dhbw-mannheim.de
reinhold.huebl@dhbw-mannheim.de
m.ahmed@plymouth.ac.uk

**Abstract:** Prior knowledge in mathematics has repeatedly been found related to study success in engineering, making its lack a variable to identify "at risk" students. Not all secondary school graduates are equally prepared to meet the demands of an engineering programme; different school types and mathematics curricula lead to broad differences in basic knowledge. As a remedy, universities offer pre-courses or bridging courses in mathematics, more and more frequently employing e-learning or blended learning programmes. The paper describes the development of an online course for study preparation in mathematics. The design process is accompanied by a research project that analyses both quality of the learning material and performance of the participants. In a multiphase research design repeated evaluations of test results, questionnaire data and statistical information are used to revise and successively improve the programme. The overall goal is to build a pre-course that meets the demands of the group of prospective engineering students. The main research interest is to build a consistent data model that relates students' personal and demographic backgrounds, prior knowledge in mathematics, and learning outcomes in the pre-course. In the first design phase, or pre-study, the most relevant issues that should be addressed in the further course of the project were identified, applying qualitative methods to question (or confirm) quantitative outcomes. Based on these results, learning material and quantitative tools were modified, and re-evaluated. The final data model for the main study is based on three quantitative sources: pre- and posttest performance, personal questionnaire, and evaluation questionnaire. The results so far reveal a highly heterogenic learner group regarding cognitive and metacognitive variables. While many students are able to close minor gaps via self-study, others lack the ability to self-regulate and need support structuring and monitoring the learning process. Thus different learning scenarios, from self-study to blended learning to online tutoring, were provided and evaluated in 2014. In the article examples for the use of learning analytics in the developmental design process and the latest version of the programme are given. The pre-posttest design's reliability was increased based on statistical analyses of students' test results. Test results then could be related to known predictors of mathematics performance, e.g. school grades, or attitude towards mathematics. Analytics were also made accessible for students by relating individual results to the peer group's overall score. Finally, pretest results were used to cluster students with similar results and assign them to matching learner groups. In the further course of the project the data collected in the pre-course will be related to external datasets, like first year exams in mathematics, and overall study success. It will be investigated if and how these correlate with learning progress in the pre-course and predictive variables like prior knowledge, type of secondary school, or attitude towards mathematics. Findings are incorporated into a joint research project funded by the German Federal Ministry of Education and Research (www.optes.de).

**Keywords:** e-assessment, design based research, self-study, mathematics, STEM

## 1. Introduction / background

In the last decade, the number of students entering higher education has grown considerably, entailing an increase in diversity of educational background (Lawson, 2003). Not all first year students are adequately prepared for their chosen course of study, and especially in engineering it is quite challenging to close gaps in school mathematics and at the same time meet the demands of the course programme. The "lack of preparedness" (Croft et al., 2009: 109) has not only been observed in the UK (Appleby et al., 2000) but in Germany as well (Fischer and Biehler, 2011). As a result, preparatory courses in Mathematics have become the rule rather than the exception. In these courses, school contents are recapitulated and related to mathematics at university level, thus trying to ease the transition from secondary to tertiary education. E-learning or blended learning courses are one approach to address the heterogeneous group of pre-course participants as they allow for higher flexibility in both content provision and time management.

The project described in this paper was initiated in 2010 and started with an entry-test, learning modules provided as pdf-files, an online posttest and an evaluation questionnaire. Based on the first year's experiences it was decided to build up an online self-study platform, combined with a research project monitoring not only test and evaluation results but the design process as well. The pre-study that was conducted in 2011 and 2012 led to the selection of a set of didactical, technical and motivational issues that were addressed in the subsequent years.

### 1.1 Multiphase design and learning analytics

An open design approach seemed appropriate for the project as students could benefit from the programme at an early stage. Learning material and evaluation tools were developed successively, and data collected from each cohort helped the designers to improve the following release. The focus on development allowed identifying problems not anticipated by the designers and addressing them immediately. This approach has been suggested for projects that involve the development, roll-out, and evaluation of information technology, or e-learning software (Richey et al., 2004). It takes into account that educational designs cannot be completely specified by the designers; interactions between participants (teachers, students), and the learning material will almost inevitably influence the setting, and may interfere with the research interest. A developmental design approach allows using the openness of the situation and investigating a set of variables and correlations between them instead of just one (Wang and Hannafin, 2005).

With the technology at hand to collect and administer large datasets it has become easier to follow this proposition. "Educational data mining" (Romero and Ventura, 2010) has been found valuable for analysing and predicting student performance (Macfadyen and Dawson, 2010) as well as for operational decision making.

As for the mathematics pre-course, a learning analytics approach was used to investigate the relation between domain-specific prior knowledge, learner behaviour, and learning success. With reference to known predictors of mathematics achievement personal and demographic data were collected, as well (Mullis et al., 2009; Fischbach et al., 2013). For each evaluation, test and questionnaire data collected from the LMS (learning management system), were analysed and, if needed, conceptual changes made. In order to triangulate the information derived from the quantitative tools a set of group interviews with pre-course participants was conducted in 2011 and 2012. This combination of qualitative and quantitative evaluation helped to decide the priorities for the further course of the project (Creswell & Plano Clark, 2011).

## 2. Project overview

The self-study programme in mathematics is open for all prospective students at the faculty of engineering. The course starts each year at the beginning of July, thus leaving three months' time for study preparation. Participation is voluntary and access to the e-learning resources is free of charge. In the privacy statement students are informed that their results and user data are treated confidentially and will be anonymised. The technical platform is an installation of the free LMS Moodle. Figure 1 shows an overview of the self-study programme's elements in the version enacted in 2014. The e-learning platform provides an initial diagnostic test, learning modules covering ten basic mathematical fields, and a final control-test. Students that still perform poorly in the latter are advised to visit additional mathematics tutorials during the first semester.

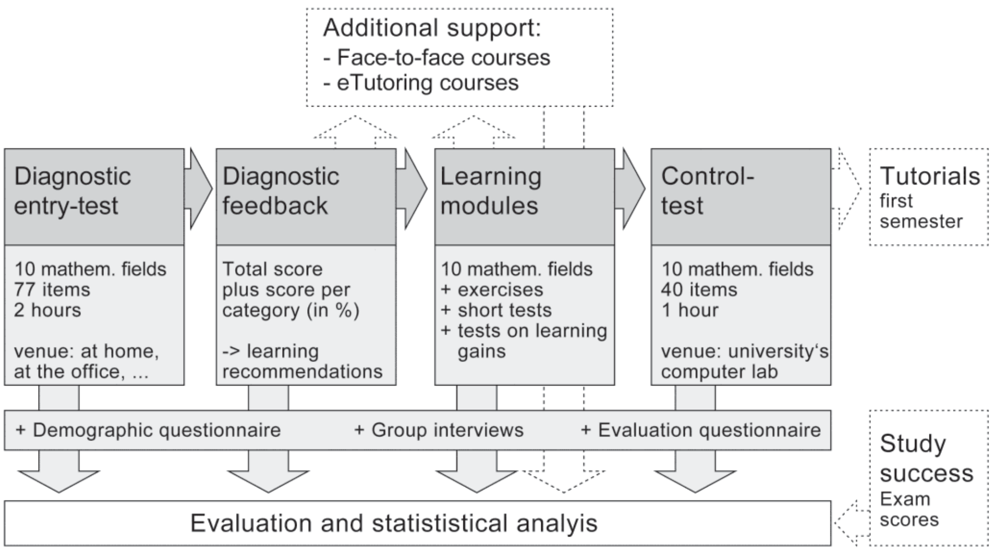



**Figure 1:** Overview of the pre-course elements and collected datasets

## 2.1 Data sets and sample

### *2.1.1 Quantitative data*

*Pre-and posttest:* As a measure of prior mathematics knowledge the diagnostic entry-test is the starting point of the learning programme. Its role is to inform students of their level of basic mathematics knowledge meets the demands of their chosen degree programme. If deficits are identified the diagnostic test feedback then enables students to plan and structure their learning. The pre-course is concluded by the control-test which is taken at the university's computer labs during induction week. In the last four years the number of complete datasets (pretest + posttest + demographic information) increased from 69% in 2011 to 84% in 2014.

**Table 1:** Number of students and pre-course participants from 2011 to 2014

| | *pre-study* | | | |
|---|---|---|---|---|
| | *2011* | *2012* | 2013 | 2014 |
| First year students | *724* | *876* | 738 | 722 |
| Pre-and posttest participation | *506* | *654* | 604 | 603 |
| Posttest only | *212* | *197* | 121 | 105 |
| Missing | *6* | *25* | 13 | 14 |

*Inventories:* Two online questionnaires were used to collect statistical data and evaluate the e-learning programme. The first questionnaire covered demographic and personal data, e.g. gender, type of secondary school, mathematics school grades, and attitude towards mathematics. The second questionnaire addressed satisfaction with the e-learning programme, e.g. level of difficulty, usability, and technical performance.

### *2.1.2 Qualitative data*

In order to better understand students' problems with and expectations of the preparatory course two sets of group interviews with first-year students were conducted during the pre-study (2011: n = 14; 2012 n = 11). After transcription the interview statements were clustered to 1. feedback on learning contents (e.g. level of difficulty, intelligibility of texts), 2. feedback on usability, and 3. students' individual learning strategies. Based on these data the evaluation questionnaire was revised, adding items addressing students' attitude towards mathematics learning, effort regulation, and helpfulness of different didactical elements of the e-learning design (see also section 3.2).

### *2.1.3 Description of the samples (2011-2014)*

On average, thirteen per cent of the students were female which is representative for the gender relation in engineering degree programmes in Germany (cf. National Report on Education, 2012). The majority of first-year students (70%) were either 19 or 20 years old. Roughly a quarter of each year's cohort already lived near the university, but most participants came from other areas in Germany. The most frequently attended secondary school type was the "Gymnasium" (approx. 70%), followed by subject-related secondary schools ("Berufliches Gymnasium", 15%), and schools leading to "Fachhochschulreife", a certificate that allows studying at Universities of Applied Sciences only (10%). Asked about their mathematics grades at school, more than 25% of the participants claimed that they had performed very good (A*/A) in mathematics, 52% good (A/B), 19% average (B/C) and 2% below average (D and lower) (2% stated that they had nearly all grades from A to D). A comparison of the four cohorts revealed similar distributions in the collected demographic variables, indicating that the student body does not change significantly from year to year.

## 2.2 Main design revisions based on pre-study data

Quantitative and qualitative pre-study outcomes revealed a set of minor problems that could be solved rather quickly, e.g. technical issues or the revision of learning contents that were found too difficult or too complex. These general evaluation outcomes will not be reported in detail. The following two aspects were considered most relevant for the didactical concept of the pre-course:

*Formative e-assessment:* Nearly all interview or open question comments revealed a high approval of online tests, and many participants demanded even more opportunities to self-assess. It therefore was decided to put a focus on the formative e-assessment concept and use its potential for activation and motivation (Black et al., 2003).

*Modularisation:* Regarding the learning process, student feedback was far from homogeneous. While many students wanted to learn independently, and alone, others claimed to need additional support and missed face-to-face sessions. Considering the differences in participants' starting positions and their personal situation in the phase between school and university it was decided to modularise the programme, with different learning scenarios open for self-selection.

In the remainder of this paper three examples are provided that document the use of learning analytics to address these issues. With the high importance of the diagnostic test for all subsequent learning activities it was decided to analyse the test's reliability, and that of the pre-posttest design (see section 3.1). Furthermore, the diagnostic entry-test feedback was revised (section 3.2) and elements of the modularised programme are described in section 3.3.

## 3. Design revisions

### 3.1 Analysis and improvement of quantitative tools: pre-posttest design

Placement tests in Mathematics are not mandatory at German universities, therefore no standardised test items were available for the development of the diagnostic test. The joint mathematics curriculum as suggested by a group of educators from different school systems and university engineering faculties was used as a reference (see cosh, 2014; and Core zero curriculum, SEFI, 2002). Furthermore, suggestions from the university's mathematics lecturers were incorporated into the first version of the test. The posttest, documenting a student's knowledge level at the end of the pre-course, was designed to be equally difficult, but consisted of different items as suggested for single group pre-posttest designs (Kane, 2013). After being reviewed by three experts (mathematics lecturers) and a test-run with university students, both tests were published on the e-learning platform.

The first cohort's test results then served as a database for classical and probabilistic item analyses. Inter-item and item-test-correlations helped to identify outliers, or items that did not correlate with the overall test results. An IRT (Item Response Theory) approach was used to model each item's difficulty. In IRT, item difficulty and participant ability are related to each other in an interdependent equation, with item properties expressed by level of difficulty and discriminating power. The probability that participants will answer an item correctly is thus influenced by these properties, in relation to their abilities (Hambleton and Swaminathan, 2010). Items that do not fit the model are likely to be unfair, as they address a hidden trait. For example, a mathematics problem might be embedded in a narrative that demands a high level of verbal proficiency.

As all items were dichotomous, a simple Rasch analysis could be performed (Embretson, 1996). For the Rasch analysis the free R software package eRm was used (Mair and Hatzinger, 2007) (all other analyses were performed with SPSS, Version 20). Items unfit to the model were considered for revision or replacement, so that each year the number of outliers could be minimised. In 2013 both tests' internal consistency was considered acceptable (Cronbach's $\alpha$ between .910 in the pretest and .852 in the posttest) and in 2014 the design remained unchanged.

On average, fifty per cent of the entry-test items were answered correctly in 2013 and 2014. In both years, and in the pre-study respectively, variance was rather high (see Table 2). The average control-test results showed a moderate but significant increase in score (repeated measurement ANOVA for both years: $p < .001$).

**Table 2:** Diagnostic entry-test and control-test results in 2013 and 2014

| | | n | mean | stand. dev. | min. | max. |
|---|---|---|---|---|---|---|
| Diagnostic entry-test | 2013 | 604 | 50,0 | 16,62 | 9,41 | 91,76 |
| | 2014 | 603 | 49,7 | 15,98 | 7,06 | 92,94 |
| Control-test | 2013 | 604 | 55,1 | 17,91 | 13,33 | 95,56 |
| | 2014 | 603 | 55,2 | 17,46 | 15,56 | 97,78 |

Students that had not participated in the pre-course (nor taken the entry-test) had control-test results that were quite similar to the entry-test scores (2013: n = 121, mean = 49.3, stand. dev. = 18.4; 2014: n = 105, mean = 47.3, stand. dev. = 18.2), so that it could be assumed that both tests were equally difficult.

As stated above, students' educational backgrounds were quite heterogeneous, therefore it was investigated if and how these test results could be related to personal and demographic variables. Analysis of variance (ANOVA) was employed to examine if the test results of different groups of students showed significant deviations. While variables like age, gender, or degree programme, were not related to test results, differences could be found for "type of secondary school", "final school grades", "mathematics grades", and for adjacent variables, like "attitude towards mathematics". In all four years, these differences were significant ($p < .001$), but again it should be stated that the variance was relatively high.

Students that had started their degree programme at the beginning of the pre-study, in 2011, graduated in 2014 with a bachelor degree. These students' course progress could be monitored in order to relate prior knowledge and overall study success. For example, the 2011 control-test results were found significantly correlated to the first-year mathematics examination ($n = 700$, $r = .46$, $p<.001$). Results in the Mathematics I exam were found significantly correlated with a student's grade point average (GPA) ($n = 690$, $r = .63$, $p < .001$).

In summary, the combination of learning analytics and statistical analysis led to a consistent data model that relates personal and demographic variables, pre- and posttest performance in the pre-course, first-year exams, and overall study success.

## 3.2 Improvement of feedback

With an improved test design, the next step was the revision of the diagnostic entry-test feedback. In its initial version students were informed of their overall scores and their results in each of the ten mathematical categories. Based on scores per category, a related learning module was recommended, or not. One important outcome of the group interview analysis was that students often felt insecure how to interpret their test results, so that the diagnostic feedback failed to deliver a meaningful "calibration" (Winne, 2004). This impression was supported by the questionnaire evaluation of the following year: Especially students with a high number of learning recommendations, based on poor results, found it difficult to use the feedback effectively and often felt demotivated by the mere amount of learning material.

Two major modifications were therefore made: First, the curriculum was re-structured, so that now six mathematical categories and learning modules built the *basic* curriculum; in the accompanying text students were informed that these contents are considered mandatory. The remaining four learning modules were re-defined as *add-ons*, advised for students wanting to prepare more deeply for their first year mathematics lectures.

The second change referred to the provision and interpretation of scores. Students who had received a poor entry-test result often felt frustrated, and thus demotivated. It was discussed to confine the diagnostic feedback to hints and learning recommendations only, as the provision of scores or grades might promote performance-oriented learner behaviour (Dweck, 1986; Gibbs and Simpson, 2004). On the other hand, transparency has been found important for the design of "good feedback" (Nicol and Macfarlane-Dick, 2006) and it was considered inevitable to inform students how the automatized feedback was computed. Furthermore, only if deficits are specified remedial actions can be initiated; and it has been shown that students will appreciate a clear and authentic feedback, even if it entails a negative influence on their self-confidence (Akey, 2006).

Finally it was decided to retain the score information but add the reference "performance of other groups" (Kluger and DeNisi, 1996: 260). Students now could compare their own test result (overall and per mathematical category) with that of previous cohort's test results (see Figure 2). The evaluation of 2014 suggests that the revised diagnostic entry-test and feedback were more helpful for students than its initial version. Positive comments on the diagnostic test ("was helpful" or "was very helpful") rose from 20% in 2013 to 65% in 2014 ("was somewhat helpful": 30%, "was not helpful": 1%).

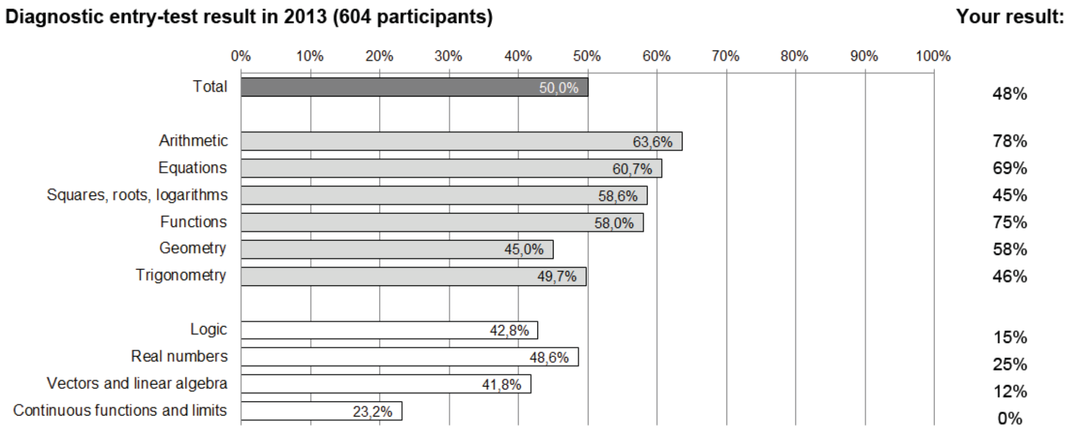



**Figure 2:** Screenshot diagnostic feedback: average entry-test results of previous cohort: Overall, six basic categories, four add-on categories (translation from German original)

## 3.3 Additional support

In 2012 and 2013, additional face-to-face courses had been offered for students that graduated from secondary schools with "Fachhochschulreife" (comparable to a technical college), or had been out of school for some time. Students with this background tended to have larger deficits and appeared to be less prepared for learning independently; therefore this group got extra support(2011: n = 44; 2012: n = 84). The pre-study revealed, though, that many other students were in need of additional support, as well. Mostly students with low mathematics knowledge had problems to effectively organise their learning process, or self-regulate (Pintrich and de Groot, 1990).

Given the university's limited resources the concept was adjusted in 2014. The weeklong face-to-face courses were now open for all students, but no longer free of charge. In addition, students could sign up for an e-tutoring programme that lasted one month. Students not (yet) living near the campus thus could also benefit from the additional programme, and the longer duration of the course allowed for more practise and individual feedback. The e-tutoring concept was based on the experiences made by a partner university (Halm et al., 2013) and adapted to the course material. While based on the same contents, learning in the e-tutoring course was structured and monitored. Students could discuss single items and test results with peers and e-tutors and had to weekly upload a completed exercise sheet. This open item format allowed tutors to review and comment on a student's individual approach to a problem.

Learning analytics outcomes in this example were used as a basis for group composition. Students with similar patterns in their diagnostic entry-test result were assigned to the same group and thus had the same schedule and e-tutor. It was expected that this pre-selection would make it easier to address the group and their individual needs.

# 4. Results 2014

In 2014, learning outcomes in the pre-course were evaluated with regards to the different elements of the modularised programme. Achievement was measured via learning gains, the difference between posttest and pretest results. On average, the result increased from 49.7 in the diagnostic entry-test to 55.2 in the control-test (see also section 3.1).

42% of the entry-test participants decided to enrol in an additional programme; 119 students visited a face-to-face course and 132 opted for the e-tutoring version. Students in the e-tutoring course had an average entry-test result of 47.5 and a control-test result of 54.2 (out of 100). Participants of the face-to-face course had a pretest result of 43.7 and a posttest result of 47.3. The highest learning gains were achieved by students that participated in both programmes (n = 28), with an entry-test result of 44.2 and a control-test result of 53.3.

The results suggest that the didactical concept of the e-tutoring course, with more online self-assessments, longer course duration, and weekly exercises with individual feedback, had a stronger impact on learner engagement and overall achievement. A limitation to this interpretation is that the groups were not randomized but self-selected into one of the learning environments. Therefore differences in prior knowledge and educational backgrounds have to be accounted for, as well: Additional programmes were more frequently chosen by students with low entry-test results, and in this sub-sample face-to-face students' test results were weaker than those of the e-tutoring students. The evaluation also revealed that many face-to-face students did not engage in further self-study activities once the class sessions were over.

## 5. Conclusion

In this paper the development, repeated evaluation and design revision of an e-learning pre-course in mathematics was described. In a pre-study learning analytics and predictive analytics were combined with quantitative data (group interviews) in order to identify the most urgent issues that were to be addressed in the further course of the project. Quantitative tools were improved by repeated statistical analysis. In the final version, the mathematics pre- and posttest were found consistent and significantly related to other predictive variables and the Mathematics I exam, which in return was strongly related to overall study success of the 2011 cohort that graduated in 2014.

The variance in learners' preferences, schedules and motivations was acknowledged and reflected in a modular and open design. Additional support was needed and actively used by students with large knowledge gaps. The comparison of learning outcomes in the different conditions – self-study, support via face-to-face, and support via e-tutoring – suggested that the latter had a much stronger effect on learning gains, probably due to its more binding concept and longer periods of practise. We also observed that students with very low prior knowledge preferred the face-to-face course and more often refused to use the self-study material, indicating that this group also was less prepared for self-regulated learning (Zimmerman, 1989).

In this project it was also attempted to make data mining outcomes accessible for students and inform them of the reference point "peer results". This approach was found helpful for students who had problems interpreting their diagnostic entry-test results and lead to higher satisfaction with this tool. Students' diagnostic test result patterns were also employed to assign them to matching learner groups in the e-tutoring course.

While the developmental research approach (Richey et al., 2004) and its combination with learning analytics were found appropriate for the project goal to develop an e-learning programme for a heterogeneous group of learners, some drawbacks should be mentioned, as well. First, the process of repeated evaluation and revision was very time consuming; in this project much time was lost due to upgrades on the LMS that entailed cumbersome revision of the learning material and related database queries. Secondly, learning analytics offer countless possibilities for statistical analysis, and the mere amount of data might tempt researchers (or administration) to "believe" them (Campbell and Oblinger, 2007: 17). Our data support the view that mathematics prior knowledge is closely related to university achievement (Parker, 2005) but these relations may not be strong enough to predict an individual student's overall study success, or failure. Finally, students should not get the impression of being constantly observed in their learning, neither by the system nor by educators or tutors. Although high standards of data privacy were applied in this project, and repeatedly communicated to participants, some students' reluctance to work online might be related to their fear of being exposed.

Future work will involve a deeper investigation into the quality of the data model and into the interplay between personal and demographic factors, prior knowledge, and study success an engineering degree programme. In cooperation with partner universities the impact of preparatory courses will be investigated in a broader context, adding learning programmes that address learning strategies and self-regulated learning abilities (www.optes.de. The project is funded by the BMBF, ref. number 01PL12012).

## References

Akey, T.M. (2006) "School context, student attitudes and behaviour, academic achievement. An exploratory analysis", *mdrc publications*.

Appleby, J., Lawson, D., Croft, T., Hawkes, T., Quinney, D. and Sleeman, B. (2000) "Diagnostic Testing in Theory and Practice", *Measuring the Mathematics Problem*, London.

Black, P., Harrison, C., Lee, C., Marshall, B. and Wiliam, D. (2003) *Assessment for Learning: Putting it into practice*, Open University Press.

Campbell, J.P. and Oblinger, D.G. (2007) "Academic Analytics", *EDUCAUSE Learning Initiative ELI.*

cosh cooperation schule:hochschule (2014) *Mindestanforderungskatalog Mathematik (2.0) der Hochschulen Baden-Württembergs für ein Studium von WiMINT-Fächern*.

Creswell, J. W. & Plano Clark, V. L. (2011). *Designing and conducting mixed methods research*, Sage, Los Angeles.

Croft, A.C., Harrison, M.C. and Robinson, C.L. (2009) "Recruitment and retention of students – an integrated and holistic vision of mathematics support", *International Journal of Mathematical Education in Science and Technology*, Vol. 40, No. 1, pp 109–125.

Dweck, C.S. (1986) "Motivational Processes Affecting Learning", *American Psychologist*, Vol. 41, No. 10, pp 1040–1048.

Embretson, S.E. (1996) "The New Rules of Measurement", *Psychological Assessment*, Vol. 8, No. 4, pp 341-349.

Fischbach, A., Keller, U., Preckel, F. and Brunner, M. (2013) "PISA proficiency scores predict educational outcomes", *Learning and Individual Differences*, Vol. 24, pp 63–72.

Fischer, P.R. and Biehler, R. (2011) "Über die Heterogenität unserer Studienanfänger", *Gesellschaft für Didaktik der Mathematik GDM*, *Beiträge zum Mathematikunterricht*.

Gibbs, G. and Simpson, C. (2004) "Conditions under which assessment supports student learning", *Learning and Teaching in Higher Education*, Vol. 1, No. 1, pp 3–31.

Halm, L., Heubach, M., Mersch, A. and Wrenger, B. (2013) "Zwei Seiten des Online-Lernens in mathematischen Grundlagenveranstaltungen", *Conference procedures MINT Symposion 2012*, Nuremberg, pp 177-183.

Hambleton, R.K. and Swaminathan, H. (2010) *Item response theory. Principles and applications*, Kluwer Academic Publishers, Boston, Dordrecht, Lancaster.

Kane, M.T. (2013) "Validating the Interpretations and Uses of Test Scores", *Journal of Educational Measurement*, Vol. 50, No. 1, pp 1–73.

Kluger, A.N. and DeNisi, A. (1996) "Effects of feedback intervention on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory", *Psychological Bulletin*, Vol. 119, No. 2, pp 254–284.

Lawson, D. (2003) *Diagnostic testing for mathematics: LTSN MathsTEAM Project*.

Macfadyen, L.P. and Dawson, S. (2010) "Mining LMS data to develop an 'early warning system' for educators: A proof of concept", *Computers & Education*, Vol. 54, No. 2, pp 588–599.

Mair, P. and Hatzinger, R. (2007) "CML based estimation of extended Rasch models with the eRm package in R", *Psychology Science*, Vol. 49, No. 1, pp 26–43.

Mullis, I.V.S., Martin, M.O., Ruddock, G.J., O'Sullivan, C.Y. and Preuschoff, C. (2009) *TIMSS 2011 Assessment Frameworks,* TIMSS & PIRLS International Study Center.

National Report on Education (2012) *Bildung in Deutschland 2012. Ein indikatorengestützter Bericht mit einer Analyse zur kulturellen Bildung im Lebenslauf*, Bielefeld.

Nicol, D.J. and Macfarlane-Dick, D. (2006) "Formative assessment and self-regulated learning: A model and seven principles of good feedback practice", *Studies in Higher Education*, Vol. 31, No. 2, pp 199–218.

Parker, M. (2005) "Placement, Retention, and Success: A Longitudinal Study of Mathematics and Retention", *Journal of General Education*, Vol. 54, No. 1, pp 22–40.

Pintrich, P.R. and de Groot, E.V. (1990) "Motivational and self-regulated learning components of classroom academic performance", *Journal of Educational Psychology*, Vol. 82, No. 1, pp 33–40.

Romero, C. and Ventura, S. (2010) "Educational Data Mining: A Review of the State of the Art", *IEEE Transactions on systems, man, and cybernetics*, Vol. 40, No. 6, pp 601–618.

Richey, R.C., Klein, J.D. and Nelson, W.A. (2004) "Developmental research: Studies of instructional design and development", in Jonassen, D.H. (Ed.) Handbook of Research for Educational Communications and Technology, Lawrence Erlbaum, Mahwah, pp 1099–1130.

SEFI mathematics working group (2002) "Mathematics for the european engineer. A curriculum for the twenty-first century", [online], http://sefi.htw-aalen.de/Curriculum/sefimarch2002.pdf.

Wang, F. and Hannafin, M.J. (2005) "Design-based research and technology-enhanced learning environments" Educational Technology Research and Development, Vol. 53, No. 4, pp 5–23.

Winne, P.H. (2004) "Students' calibration of knowledge and learning processes: Implications for designing powerful software learning environments", *International Journal of Educational Research*, Vol. 41, No. 6, pp 466–488.

Zimmerman, B.J. (1989) "Models of self-regulated learning and academic achievement", in Zimmerman, B.J. and Schunk, D.H. (Eds.) *Self-regulated learning and academic achievement: Theory, research and practice*, Springer, New York, pp 1–26.

A.7 Derr, K.; Hübl, R.; Podgayetskaya, T. (2015). "Development of a web-based pre-course in mathematics based on formative evaluation" (Original title: Formative Evaluation und Datenanalysen als Basis zur schrittweisen Optimierung eines Online Vorkurses Mathematik). In: N. Nistor and S. Schirlitz (eds.), Digitale Medien und Interdisziplinarität; Medien in der Wissenschaft, Band 68, Waxmann, Münster, pp. 186-196.

DOI: urn:nbn:de:0111-pedocs-113198
ISBN: 978-3-8309-3338-0

http://www.pedocs.de/volltexte/2015/11319/pdf/Nistor_Schirlitz_2015_Digitale_Medien_und_Interdisziplinaritaet.pdf

*Katja Derr, Reinhold Hübl, Tatyana Podgayetskaya*

# Formative Evaluation und Datenanalysen als Basis zur schrittweisen Optimierung eines Online-Vorkurses Mathematik

## Zusammenfassung

In diesem Beitrag wird die Vorgehensweise beim Auf- und Ausbau eines Online-Vorkurses Mathematik für technische Studiengänge beschrieben, der jährlich auf Basis der Evaluationsergebnisse angepasst und erweitert wurde. Die Entwicklung der interaktiven Lernmaterialien und formativen E-Assessments erforderte die Kombination mathematik-, physik- und mediendidaktischer Kenntnisse. Umfangreiche Abfragen auf dem datenbankbasierten Lernmanagementsystem (LMS) ermöglichten die Analyse der Qualität und Wirksamkeit des Angebots; hier kamen insbesondere testtheoretische Methoden und Verfahren zum Einsatz. Die entwickelten Instrumente sowie Erkenntnisse über Vorwissen und Lernverhalten der angehenden Studierenden fließen in das Hochschulverbundprojekt *optes* ein. Im Gegenzug konnte die dort vorhandene Expertise im Bereich des E-Mentoring zum Aufbau eines Betreuungskonzepts genutzt werden. Die Evaluationsergebnisse des Jahrgangs 2014 werden vor dem Hintergrund der Frage dokumentiert, welche Betreuungsangebote für welche Lernenden geeignet erscheinen.

## 1 Einleitung

Vor- und Brückenkurse in Mathematik sind ein wichtiger Bestandteil der Vorbereitung auf technische Studiengänge und werden mittlerweile an fast allen Hochschulen angeboten. Dabei werden mathematische Grundlagen aus der Mittel- und Oberstufe in komprimierter Form wiederholt, um den StudienanfängerInnen den Einstieg in die Hochschulmathematik zu erleichtern. Angesichts der heterogenen Ausgangsvoraussetzungen und Lebenssituationen der TeilnehmerInnen bietet sich die Vermittlung dieser Lerninhalte über E- bzw. Blended-Learning-Formate an (Bausch et al., 2014). Im vorgestellten Projekt wurde im Jahr 2010 mit dem Aufbau eines Online-Vorkurses Mathematik für die Fakultät Technik der Dualen Hochschule Baden-Württemberg (DHBW) Mannheim begonnen, der sich zu einem interaktiven Lernraum mit Online-Betreuungsphasen entwickelt hat. Im Jahr 2012 wurde das Projekt in das BMBF-geförderte Verbundprojekt *optes* eingegliedert, in dem im Rahmen des







Qualitätspakts Lehre Angebote zur Unterstützung der Studieneingangsphase konzipiert und erprobt werden.

Die sukzessive Entwicklung und Optimierung der Lernplattform hatte den Vorteil, dass die Lernenden schon zu einem relativ frühen Zeitpunkt auf die (noch nicht interaktiv aufbereiteten) Materialien zugreifen konnten. Unerwartete Probleme, Kritik und Wünsche der TeilnehmerInnen konnten dann beim weiteren Ausbau berücksichtigt werden. Darüber hinaus wurden die Daten genutzt, um die eingesetzten Instrumente zu evaluieren. Durch diesen offenen Ansatz konnte flexibel auf konzeptionelle, inhaltliche oder technische Unstimmigkeiten reagiert werden, das Untersuchungsdesign wurde parallel zu den Lernmaterialien überarbeitet und verbessert (Richey et al., 2004). Zur Triangulation der quantitativen Daten wurden außerdem in den Jahren 2011 und 2012 mehrere Gruppeninterviews mit StudienanfängerInnen zu ihrer Nutzung des Vorkursangebots geführt (Creswell & Plano Clark, 2011). Die Analyse der Datensätze der Jahrgänge 2011 und 2012 führte zu einer Reihe von Korrekturen, wie z.B. der Anpassung des Schwierigkeitsgrads, der Erweiterung bzw. Kürzung von Lerninhalten oder der Optimierung technischer Abläufe. In Bezug auf die Entwicklung der Instrumente und des didaktischen Designs wurden folgende zentrale Aufgabenstellungen für die weitere Arbeit formuliert:

*1. Modularisierung:* Die angehenden Studierenden unterscheiden sich in ihrer Wohn- und Lebenssituation zum Zeitpunkt des Vorkurses; um möglichst alle angehenden Studierenden ansprechen zu können, sollte das Angebot sowohl zeitlich als auch räumlich so flexibel wie möglich gestaltet sein. Die Vorkurs-TeilnehmerInnen haben unterschiedliche schulische und berufliche Hintergründe, auch ihre Vorkenntnisse in Mathematik differieren teilweise erheblich (Fischer & Biehler, 2011). Oft bestehen nur kleinere Wissenslücken in Mathematik, die problemlos im Selbststudium geschlossen werden können. Ein Teil der StudienanfängerInnen ist hingegen mit großen Defiziten im Grundlagenbereich konfrontiert oder verfügt nicht über die Fähigkeit, diese im Selbststudium zu bearbeiten. Für diese Gruppe werden zusätzliche Unterstützungsangebote erprobt und ausgewertet.

*2. Formatives E-Assessment:* Die in der Pilotphase eingesetzten Selbsttests werden im Hinblick auf Qualität und Aussagekraft des diagnostischen Feedbacks untersucht und optimiert. Über den zielgerichteten Einsatz von Selbsttests und Übungsaufgaben sollen Lernende außerdem in höherem Maße aktiviert und motiviert werden.

## 2 Qualitätskontrolle und Redesign

Das Basisangebot, das alle angehenden Studierenden der technischen Fakultät zur Studienvorbereitung nutzen können, besteht aus einem umfassenden Online-Selbsttest, dem darauf basierenden diagnostischen Feedback, interaktiven Lernmodulen sowie einem Kontrolltest zur Überprüfung des Lernerfolgs. Auf Basis der Kontrolltestergebnisse erhalten die StudienanfängerInnen dann Empfehlungen für die Teilnahme an Mathematik-Tutorien während des ersten Semesters.

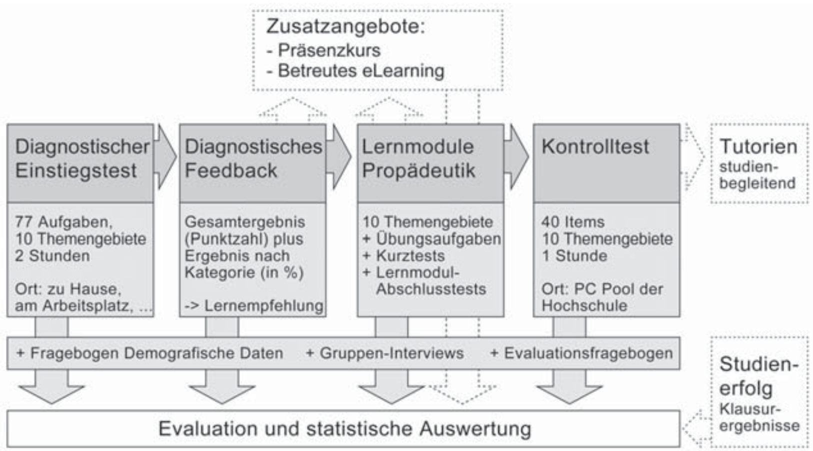



Abb. 1: Online-Studienvorbereitung Mathematik: Basisangebot auf der Lernplattform (LMS) und optionale Zusatzangebote für den Jahrgang 2014/15

### 2.1 Überprüfung der Qualität der Instrumente

Die Instrumente zur Selbstdiagnose und Lernerfolgskontrolle wurden von Anfang an als Online-Tests bereitgestellt, damit die Möglichkeiten des automatisierten Feedback genutzt werden konnten. Bei der Testkonstruktion standen zunächst inhaltliche Fragen im Vordergrund, so sollte der diagnostische Selbsttest das Curriculum der Mittel- und Oberstufe abdecken (cosh, 2014) und den Lernenden dann möglichst passgenaue Empfehlungen zur Arbeit mit den Lernmodulen geben. Damit Flüchtigkeitsfehler nicht überbewertet werden, ist jedes der zehn Themengebiete durch mehrere Items repräsentiert, außerdem kommen nur niederschwellige Aufgabentypen wie Multiple Choice und numerische Eingabe zum Einsatz. Beide Tests wurden im Vorfeld durch drei ExpertenInnen geprüft (MathematiklehrerInnen eines Gymnasiums sowie







Mathematik-Dozierende der Hochschule) und von Studierenden getestet, bevor sie im Vorkurs zum Einsatz kamen.

Die Testergebnisse des ersten Jahrgangs wurden genutzt, um die Qualität der beiden Tests und ihre Tauglichkeit zur Messung des Lernerfolgs zu überprüfen. Ziel war die Identifizierung von Aufgaben mit geringem Informationsgehalt (zu leicht, zu schwer) oder unerwarteten oder „unfairen“ Ergebnissen (Aufgaben, die für unterschiedliche Teilnehmergruppen unterschiedlich schwer sind). Neben Item-Test-Korrelationen wurden probabilistische Verfahren zur Analyse der Schwierigkeit auf Item- und Testebene eingesetzt (Rasch-Modell). Nicht „modell-konforme“ Items wurden überarbeitet oder ersetzt, so konnten die beiden Tests schrittweise optimiert und skaliert werden[1]. Ziel war die Angleichung des Schwierigkeitsgrads von Einstiegs- und Kontrolltest, zur Messung des Lernerfolgs sollten zwei vergleichbar schwere, aber nicht gleiche Tests zum Einsatz kommen (Kane, 2013). Während in den ersten beiden Jahren noch relativ viele Anpassungen vorgenommen werden mussten, lieferten die Tests 2013 zufriedenstellende Ergebnisse (Cronbachs $\alpha$ zwischen .910 im Einstiegstest und .852 im Kontrolltest) und wurden 2014 unverändert eingesetzt. Die genannten Qualitätsanalysen werden auch im weiteren Projektverlauf durchgeführt.

### 2.2 Modularisierung

Nicht alle StudienanfängerInnen verfügen über angemessene Lernstrategien, um Lerninhalte im Selbststudium zu bearbeiten. Ein realistisches Zeitmanagement, die Schaffung eines lernförderlichen Umfelds, aber auch der Umgang mit Motivationsproblemen sind jedoch Voraussetzung für einen erfolgreichen Lernprozess (Zimmerman, 1989). Diese Fähigkeit zum „selbstregulierten Lernen“ korreliert oft mit fachlichem Vorwissen (Baumert et al., 2000). Lernenden mit guten Fachkenntnissen fällt es leichter, unterstützende Online-Tools effektiv für den Lernprozess einzusetzen (Renkl & Atkinson, 2003). Ein großer Prozentsatz der TeilnehmerInnen des Online-Vorkurses verfügte über solide fachliche und überfachliche Vorkenntnisse und schätzte die Möglichkeit, auf der Plattform selbständig und im eigenen Tempo zu lernen, während sich vor allem TeilnehmerInnen mit eher niedrigen Einstiegtestergebnissen Unterstützung bei der Einschätzung dieses Resultats und bei der Gestaltung des Lernprozesses wünschten.

*Zusatzangebote: Präsenz*. Insbesondere SchülerInnen mit Fachhochschulreife empfanden die Lernmodule als eher schwer und hatten oft Schwierigkeiten mit ihnen unbekannten mathematischen Ausdrücken oder zu knapp gehaltenen Lösungswegen im Aufgabenfeedback. Auch nach der Überarbeitung der

1 Als Software wurde das R-Package eRm genutzt (Mair & Hatzinger, 2007).

Lernmodule im Hinblick auf diese Probleme waren die Lernerfolge dieser Gruppe am geringsten, so dass schon im Jahr 2012 zusätzliche Präsenzkurse für StudienanfängerInnen mit Fachhochschulreife angeboten wurden. Diese einwöchigen Kurse fanden jeweils im September statt und waren inhaltlich und konzeptionell auf die Online Lernmaterialien abgestimmt. Der Lernerfolg der TeilnehmerInnen konnte allerdings durch diese Kurse nicht signifikant angehoben werden. Die Evaluation ergab, dass nur wenige Lernende über die Präsenzphase hinaus auf der Lernplattform aktiv waren, sodass die investierte Lernzeit ganz offensichtlich nicht ausreichte, um die teilweise erheblichen Wissenslücken zu schließen. Angesichts knapper Ressourcen und wachsender Nachfrage wurden die Konzepte überarbeitet und die Präsenzangebote für alle StudienanfängerInnen geöffnet, können nun aber nicht mehr kostenfrei angeboten werden.

*Zusatzangebote: Betreutes E-Learning*. Zusätzlich wurde das Angebot 2014 um einen einmonatigen (kostenfreien) Kurs „betreutes E-Learning“ erweitert. Ziel dieses Angebots ist die stärkere Aktivierung und Motivierung der Lernenden durch den Kontakt zu einem Fachdozierenden bzw. zu E-MentorInnnen und einer Lerngruppe sowie eine stärkere Strukturierung des Lernprozesses. Bei der Entwicklung des Konzepts konnte auf Erfahrungen der Hochschule Ostwestfalen-Lippe, einer Partnerhochschule im Verbundprojekt, zurückgegriffen werden (Halm et al., 2013). Gemäß dem Prinzip der „minimalen Hilfe“ werden die Lerninhalte zunächst in Eigenregie bearbeitet, bei Bedarf werden dann Peers oder Lehrpersonen im Online-Forum um Tipps zur Lösung eines Problems gebeten (z.B. Aebli, 2011). In den vier Wochen Kursdauer werden vier von sechs grundlegenden Lernmodulen bearbeitet. Der zentrale Unterschied zum Selbststudium liegt in der höheren Verbindlichkeit. Die Kursteilnahme wird nur bestätigt, wenn ein Teilnehmer vier Aufgabenblätter rechtzeitig bearbeitet und eingereicht hat (ein Aufgabenblatt pro Thema und Woche). Dieses offene Aufgabenformat ermöglicht den Dozierenden einen Einblick in die einzelnen Rechenschritte der TeilnehmerInnen. Anders als bei geschlossenen oder halb offenen Online-Aufgabentypen können sie so nachvollziehen, ob und an welcher Stelle eines Lösungsansatzes eine Fehlkonzeption vorliegt und diese gezielt adressieren.

*Aktivierung und Motivation*. Als ein weiteres Handlungsfeld des Redesigns wurde der Aufbau eines Fragepools mit technischem Anwendungsbezug definiert. Vielen TeilnehmerInnen am Vorkurs fiel es schwer, sich über einen längeren Zeitraum für die Beschäftigung mit mathematischen Grundlagen zu motivieren. Über die Verbindung der mathematischen Verfahren mit physikalischen oder technischen Anwendungsbeispielen soll der Bezug zum eigentlichen Studieninteresse hergestellt und das Interesse an mathematischen Fragestellungen erhöht werden. Die Herausforderung bei diesem Ansatz ist es, Aufgaben zu finden, die gleichzeitig authentisch und mit dem Vorwissen der







StudienanfängerInnen lösbar sind (Wolf & Biehler, 2014). Die Entwicklung von nachvollziehbaren und realistischen Beispielen ist zeitaufwändig und muss in Abstimmung mit ExpertInnen aus der Physik bzw. den ingenieurwissenschaftlichen Fakultäten erfolgen (Preißler et al., 2010). Für den Bereich des Selbststudiums werden Übungsaufgaben entwickelt, in denen die Praxisbeispiele als „Anker“ für das spätere Berufsziel dienen, während im betreuten E-Learning auch komplexere Problemstellungen zum Einsatz kommen, die dann im Austausch mit Peers oder Dozierenden schrittweise gelöst werden (Leutner et al., 2008).

## 3 Evaluationsergebnisse 2014

### 3.1 Erfasste Teilnehmerdaten

Am Online-Vorkurs können alle angehenden Studierenden der Fakultät Technik teilnehmen. Die Teilnehmerzahlen lagen im ersten Jahr des Projekts bei etwa 70% der StudienanfängerInnen und sind seither jedes Jahr leicht angestiegen, auf 84% im Jahr 2014 (603 von 722)[2]. Die sechs einwöchigen Präsenzkurse wurden im Zeitraum August bis November mit 119 TeilnehmerInnen durchgeführt, der vierwöchige Kurs „Betreutes E-Learning“ fand im September mit elf Gruppen und 132 TeilnehmerInnen statt. Zu Beginn des Vorkurses wurden persönliche und demografische Daten wie Alter, Bundesland, schulischer Hintergrund und Mathematiknoten der letzten Schuljahre erfasst, außerdem enthielt der Fragebogen Items zur Einstellung gegenüber Mathematik und Mathematiklernen (Kadijevich, 2006). Der Evaluationsfragebogen nach Abschluss des Vorkurses umfasste Fragen zum Schwierigkeitsgrad, zur technischen Performance sowie allgemeinen Zufriedenheit mit dem Angebot, außerdem wurden die TeilnehmerInnen nach der investierten Lernzeit und dem Einsatz von Lernstrategien gefragt (Schiefele & Wild, 1994). Der Evaluationsfragebogen wurde von 205 TeilnehmerInnen ausgefüllt, wobei die Rücklaufquote bei den TeilnehmerInnen am betreuten E-Learning mit 65% am höchsten war (Präsenzkurs: 37%, Selbststudium: 28%).

### 3.2 Vorkenntnisse: Ergebnisse im diagnostischen Einstiegstest

Im diagnostischen Einstiegstest wurden durchschnittlich 49,7 von 100 Punkten erzielt. Wie schon in den Vorjahren wiesen die Ergebnisse eine relativ starke Streuung auf (n: 603, min.: 7,06, max.: 92,9, Standardabweichung: 16,62). Die

2 Als TeilnehmerInnen wurden StudienanfängerInnen gewertet, die am diagnostischen Einstiegstest *und* am Kontrolltest teilgenommen haben.

Analyse in Bezug auf die erhobenen persönlichen Variablen bestätigte schon bekannte Zusammenhänge zwischen schulischem Hintergrund, Einstellung und Mathematik-Leistungsmessung (z.B. Mullis, 2012). So bestand beispielsweise ein deutlicher Unterschied zwischen den Einstiegstestergebnissen der StudienanfängerInnen mit Abitur (MW: 51,8) und Fachhochschulreife (MW: 40,3). Einen ähnlich starken Einfluss auf das Einstiegstestergebnis hatten die Note im Schulabschlusszeugnis, die Mathematiknoten der letzten Schuljahre sowie die Einstellung dem Schulfach Mathematik gegenüber.[3]

### 3.3 Lernerfolg: Ergebnisse im Kontrolltest

Der Lernerfolg im Vorkurs wurde gemessen als Differenz zwischen den beiden Messpunkten „Einstiegstest" (Termin frei wählbar, mindestens einen, höchstens fünf Monate vor Studienbeginn) und „Kontrolltest" (Durchführung in der ersten Woche des Studiums in den Computerräumen der Hochschule). Insgesamt wurde eine Verbesserung von 49,7 auf 55 (von 100) Punkten festgestellt. Die Veränderung zwischen beiden Messpunkten ist signifikant ($p < .001$), allerdings ist auch hier eine starke Streuung zu beobachten. Im Unterschied zum Ergebnis im diagnostischen Einstiegstest war der Lernerfolg unabhängig von der Art der Hochschulzugangsberechtigung und der Mathematiknote, auch Geschlecht oder Alter hatten keinen Einfluss auf die Veränderung zwischen Pre- und Posttest. Deutlich war hingegen der Einfluss der Variablen zur Einstellung: Lernende mit einer positiven Einstellung dem Fach Mathematik und dem Mathematiklernen gegenüber hatten nicht nur bessere Einstiegstestergebnisse sondern auch einen stärkeren Lernzuwachs als Lernende mit einer indifferenten oder ablehnenden Haltung.

Die erfassten Variablen zum Lernverhalten brachten weniger eindeutige Ergebnisse. Zwar konnte gezeigt werden, dass sich TeilnehmerInnen des betreuten E-Learning, die viel Lernzeit investieren, auch stärker verbessern; dieser Effekt wurde aber erst bei sehr hohem Zeitaufwand sichtbar (15 und mehr Stunden pro Woche über einen Zeitraum von vier Wochen). Ein linearer und signifikanter Zusammenhang zwischen eingesetzter Zeit und Lernerfolg für alle VorkursteilnehmerInnen ließ sich nicht nachweisen, und auch andere Variablen zur Beschreibung des Lernverhalten (z.B. Erstellung und Einhalten eines eigenen Lernplans) wiesen zwar signifikante Zusammenhänge mit den einzelnen Testergebnissen, nicht aber mit dem Lernerfolg auf.

Interessant ist vor allem die Entwicklung der TeilnehmerInnen mit eher niedrigem Einstiegstestergebnis, die in den Zusatzangeboten besonders stark repräsentiert waren. Hier zeigte sich eine besonders deutliche Verbesserung der

3 ANOVA lieferte in den vier genannten Fällen ein signifikantes Ergebnis mit $p < .001$







TeilnehmerInnen, die den Kurs „Betreutes E-Learning" mit Zertifikat abgeschlossen, aber nicht an einem Präsenzkurs teilgenommen haben (n = 85). Diese Gruppe konnte sich von durchschnittlich 47,5 Punkten im Einstiegstest auf 54,2 im Kontrolltest verbessern. StudienanfängerInnen, die sich für beide Kursangebote entschieden haben (n = 28), konnten einen Lernzuwachs von 44,2 auf 53,3 erzielen. Im Vergleich dazu war der Lernerfolg der Präsenzkursteilnehmenden (n = 91) mit einer Verbesserung von 43,7 auf 47,3 geringer (siehe Abb. 2). Durch die stärkere Verbindlichkeit und die Verlängerung der Kursdauer (und damit der Übungsphasen) im betreuten E-Learning konnte vor allem der Lernerfolg von Teilnehmenden mit einem schwachen Einstiegstestergebnis (< 50) verbessert werden. Einschränkend ist zu sagen, dass die Vorkenntnisse bzw. Einstiegstestergebnisse der Teilnehmenden an der E-Learning-Variante etwas besser waren als die der Präsenzkursteilnehmenden. Dieser größere Abstand ist durch einen einwöchigen Kurs offensichtlich nicht zu schließen. Die Gruppe, die das betreute E-Learning abgebrochen hat (n = 19), hatte in beiden Tests ein unterdurchschnittliches Ergebnis und konnte ganz offenbar kaum von dem Angebot profitieren.

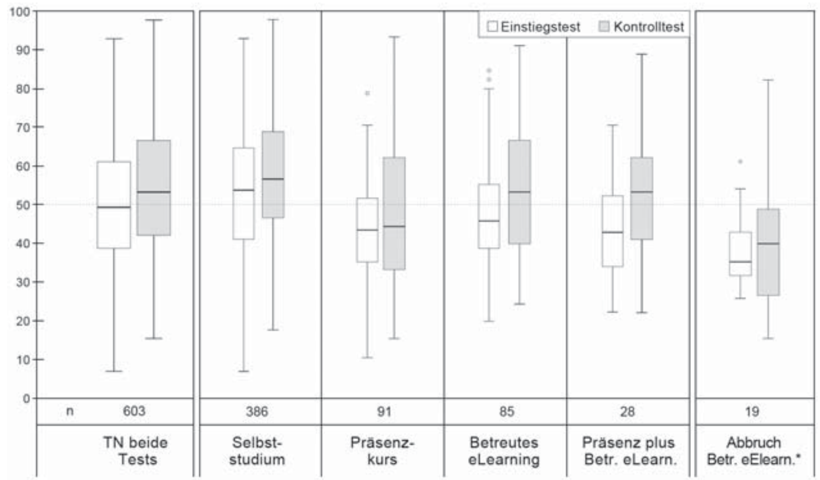



Abb. 2: Einstiegs- und Kontrolltestergebnisse 2014 in Prozent, Vergleich der Lernformen (Datenbasis: Teilnehmer an beiden Tests) (*in dieser Gruppe sind 6 Teilnehmer enthalten, die danach am Präsenzkurs teilgenommen haben)

Der Einsatz von mehr praxisbezogenen Aufgaben wurde positiv evaluiert, vor allem Teilnehmende mit schwächerem Einstiegstestergebnis bevorzugten diesen Aufgabentyp. Das Konzept der Einreichaufgaben wurde von 72% der Teilnehmenden als „hilfreich“ bzw. „sehr hilfreich“ bezeichnet. Ein Zusammenhang zwischen Lernerfolg und positiver Einstellung diesen Angeboten gegenüber konnte allerdings nicht beobachtet werden.

## 4 Fazit und Ausblick

Im vorgestellten Ansatz wurde eine Kombination unterschiedlicher Datenquellen, qualitativ und quantitativ, über einen längeren Zeitraum hinweg evaluiert, wobei die Instrumente zusammen mit den Lernmaterialien schrittweise optimiert wurden. Interdisziplinäre Schnittstellen ergaben sich in mehreren Bereichen des Projekts. Als Ausgangspunkt für die statistische Analyse waren umfangreiche jährliche Datenbankabfragen erforderlich, die über die Standardfunktionalität des LMS hinausgingen. Für die in Abschnitt 2.1 beschriebene Analyse des Pre-Postdesigns wurden Kenntnisse der Testtheorie und probabilistischer Verfahren benötigt, und auf inhaltlicher Ebene waren die Lehrpläne der Mittel- und Oberstufen in Baden-Württemberg und den angrenzenden Bundesländern zu berücksichtigen. Die Erstellung und Evaluation der interaktiven Lernmodule und Übungsaufgaben erforderte die Verknüpfung von mathematik- und mediendidaktischer Expertise sowie die Beschäftigung mit offenen und geschlossenen Aufgabenformaten. Für die Ergänzung der Lernmaterialien durch praxisbezogene Beispiele ergaben sich wiederum Schnittmengen mit den Ingenieurwissenschaften und der Physikdidaktik.

Die auf Basis der Datenanalyse entwickelte Strategie, die sehr heterogene Gruppe der StudienanfängerInnen durch ein modulares Angebot zu adressieren, hat sich bewährt. Während StudienanfängerInnen mit gutem und sehr gutem Einstiegstestergebnis kleinere Wissenslücken im Selbststudium schließen konnten, wurden insbesondere StudienanfängerInnen mit schwächeren Einstiegstestergebnissen zur Teilnahme an den Zusatzangeboten motiviert und konnten sich, mit den geschilderten Einschränkungen, im Kontrolltest teilweise deutlich steigern.

Insgesamt konnten Zusammenhänge zwischen Mathematikeinstellung und -leistung aufgezeigt werden, die schon in deutlich größeren Projekten (TIMSS, PISA) für SchülerInnen nachgewiesen wurden, sodass nun ein solides Datenmodell zur Verfügung steht, das auf die Gruppe der Ingenieursstudierenden angewandt werden kann. Ein Bedarf weitergehender Analysen besteht im Hinblick auf die Variablen zum Lernverhalten, die bislang wenig zur Erklärung des Lernerfolgs beitragen konnten. Im weiteren Projektverlauf ist der Abgleich der Vorkursergebnisse mit dem Studienerfolg am DHBW-Standort Mannheim







geplant, sowie der Vergleich der Vorkursergebnisse an den verschiedenen Partnerhochschulen im Verbundprojekt *optes*.

## Literatur

Aebli, H. (2011). *Zwölf Grundformen des Lehrens. Eine Allgemeine Didaktik auf psychologischer Grundlage*. Stuttgart: Klett-Cotta.

Baumert, J. et al. (2000). *Fähigkeit zum selbstregulierten Lernen als fächerübergreifende Kompetenz*. Berlin: Max-Plack-Institut für Bildungsforschung.

Bausch, I. et al. (Hrsg.) (2014). *Mathematische Vor- und Brückenkurse. Konzepte und Studien zur Hochschuldidaktik und Lehrerbildung Mathematik*. Wiesbaden: Springer.

cosh cooperation schule:hochschule (2014). Mindestanforderungskatalog Mathematik (2.0) der Hochschulen Baden-Württembergs für ein Studium von WiMINT-Fächern, www.mathematik-schule-hochschule.de

Creswell, J.W. & Plano Clark, V.L. (2011). *Designing and conducting mixed methods research.* Los Angeles: Sage.

Fischer, P.R. & Biehler, R. (2011). *Über die Heterogenität unserer Studienanfänger. Ergebnisse einer empirischen Untersuchung von Teilnehmern mathematischer Vorkurse.* In GDM: Beiträge zum Mathematikunterricht.

Halm, L., Heubach, M., Mersch, A., Wrenger, B. (2013). Zwei Seiten des Online-Lernens in mathematischen Grundlagenveranstaltungen: Unterstützung Lehrender und Betreuung Studierender im Selbststudium. In Tagungsband zum 1. HD MINT Symposium (S. 177–183). Nürnberg.

Kadijevich, D. (2006). Developing trustworthy TIMSS background measures: A case study on mathematics attitude. *The Teaching of Mathematics, 2*, 41–51.

Kane, M.T. (2013). Validating the interpretations and uses of test scores. *Journal of Educational Measurement, 50*(1), 1–73.

Leutner, D. et al. (2008). Instruktionspsychologische und fachdidaktische Aspekte der Qualität von Lernaufgaben und Testaufgaben im Physikunterricht. In J. Thonhauser (Hrsg.), *Aufgaben als Katalysatoren von Lernprozessen* (S. 168–181). Münster: Waxmann.

Mair, P. & Hatzinger, R. (2007). CML based estimation of extended Rasch models with the eRm package in R. *Psychology Science, 49*(1), 26–43.

Mullis, I.V.S., Martin, M.O., Foy, P. & Arora, A. (2012) *TIMSS 2011 International Results in Mathematics*, http://timssandpirls.bc.edu/timss2011

Preißler, I. et al. (2010). Treibstoff für die Ingenieurausbildung – fachübergreifende Didaktik. *Zeitschrift für Hochschulentwicklung, 5*(3), 105–115.

Renkl, A. & Atkinson, R.K. (2003). Structuring the transition from example study to problem solving in cognitive skill acquisition: A cognitive load perspective. *Educational Psychologist, 38*(1), 15–22.

Richey, R.C., Klein, J.& Nelson, W. (2004). Developmental research: Studies of instructional design and development. In D. Jonassen (Hrsg.), *Handbook of Research for Educational Communications and Technology* (S. 1099–1130). Mahwah: Lawrence Erlbaum.

A.8 Derr, K.; Hübl, R.; Podgayetskaya, T. (2015). "Online assistance in mathematics pre-courses: domain-related and interdisciplinary aspects" (Original title: Betreuungs-konzepte für Online-Vorkurse in Mathematik: Fachliche und überfachliche Aspekte). Proceedings 2nd HD-MINT-Symposium, 24-25 September 2015, Nuremberg, pp. 64-69.

ISSN: 1612-4537

https://www.th-nuernberg.de/fileadmin/abteilungen/sll/Dokumente/Publikationen-Fachartikel_PDFs/ENDVERSION_HDMINT_2015_Tagungsband.pdf

# Betreuungskonzepte für Online-Vorkurse in Mathematik: Fachliche und überfachliche Aspekte

Katja Derr, Reinhold Hübl, Tatyana Podgayetskaya
DHBW Mannheim
E-Mail: {katja.derr; reinhold.huebl; tatyana.podgayetskaya}@dhbw-mannheim.de

## Einleitung

Im Hochschulverbundprojekt optes[1] werden unterschiedliche Konzepte für das begleitete Selbststudium der Mathematik im Bereich Übergang Schule/Hochschule entwickelt und erprobt. Im Teilprojekt „formatives eAssessment", das an der DHBW Mannheim angesiedelt ist, wurde im Jahr 2014 ein modulares Vorkursangebot durchgeführt und evaluiert, das die Heterogenität der angehenden Studierenden berücksichtigt. Im Bereich der Schulmathematik ist diese ein mittlerweile recht gut dokumentiertes Phänomen (z. B. Hoppenbrock et al., 2013); auch die Einstiegstestergebnisse der optes Vorkurse weisen eine hohe Varianz auf (Derr et al., 2015). Unterschiede bestehen allerdings nicht nur auf fachlicher, sondern auch auf überfachlicher Ebene. Diese umfasst neben grundlegenden kommunikativen Fähigkeiten auch die effektive Planung, Gestaltung und Überprüfung des eigenen Lernprozesses (Boekaerts et al., 2000). Ein Mangel an „Studierfähigkeit", oder „lack of preparedness" (Croft et al., 2009), erschwert somit die Teilnahme an Vorbereitungskursen, die das Schulwissen in sehr komprimierter Form wiederholen.

Im optes Vorkurs helfen ein diagnostischer Einstiegstest und ein darauf basierendes Feedback, gegliedert nach 10 Themenbereichen, mit individuellen Lernempfehlungen bei der Selbsteinschätzung und der Planung der weiteren Lernhandlungen. Die Bearbeitung der Online Lernmaterialen im Selbststudium eignet sich vor allem für Studienanfänger/-innen, die kleinere Wissenslücken schließen möchten, und oder über angemessene Lernstrategien verfügen. Für Vorkursteilnehmer/-innen, die eine stärkere Unterstützung benötigen, wurde das Zusatzangebot „Betreutes eLearning" entwickelt und im Jahr 2014 erstmalig durchgeführt.

[1] optes – Optimierung der Selbststudiumsphase – wird im Rahmen des Qualitätspakts Lehre aus Mitteln des Bundesministeriums für Bildung und Forschung unter dem Förderkennzeichen 01PL12012 gefördert.



## Betreutes eLearning

Das Betreuungskonzept basiert auf der Arbeit des optes Teilprojekts eMentoring (Halm et al., 2013), sowie auf Erfahrungen der DHBW Mosbach, die einen ähnlichen Ansatz verfolgt (Deimling, 2012). Ziel dieses Angebots ist die stärkere Aktivierung und Motivierung der Lernenden durch den Kontakt zu Fachdozenten bzw. eMentoren und einer Lerngruppe, sowie eine stärkere Strukturierung des Lernprozesses. Auf Basis ihrer Einstiegstestergebnisse werden die Studienanfänger/-innen einer Gruppe zugeordnet, die im gleichen Zeitraum die gleichen Lernmodule bearbeitet. Gemäß dem Prinzip der „minimalen Hilfe" werden die Online-Lernmodule zunächst in Eigenregie bearbeitet, bei Bedarf werden dann Peers oder Lehrpersonen im Online-Forum um Tipps zur Lösung eines Problems gebeten (z. B. Aebli, 2011).

Neben der Strukturierung des Lernplans und der Kommunikation in der Gruppe besteht der zentrale Unterschied zum reinen Selbststudium in der höheren Verbindlichkeit. Die Kursteilnahme wird nur bestätigt, wenn ein/e Teilnehmer/in vier Aufgabenblätter rechtzeitig bearbeitet und eingereicht hat (ein Aufgabenblatt pro Thema und Woche). Dieses offene Aufgabenformat ermöglicht den Dozent/-innen einen Einblick in die einzelnen Rechenschritte der Teilnehmer/-innen; anders als bei geschlossenen oder halb offenen Online-Aufgabentypen kann so nachvollzogen werden, ob und an welcher Stelle eines Lösungsansatzes eine Fehlkonzeption vorliegt. Studienanfänger/-innen, die den Kurs im Selbststudium bearbeiten, erhalten diese Aufgaben nicht.

## Komplexität von Aufgaben

Im Konzept für den Einsatz von formativem eAssessment im Vorkurs wird berücksichtigt, welche Aufgabenformate für welchen Einsatz geeignet sind. Insbesondere im Selbststudium sollte die Komplexität nicht zu hoch sein, um Missverständnisse, Frustration und Zeitverlust zu vermeiden. Die Komplexität oder Schwierigkeit einer Aufgabe bemisst sich dabei nach dem Grad der kognitiven Anforderung, die sie an die Lernenden stellt.

In Anlehnung an Taxonomien der Verarbeitungstiefe (Anderson & Krathwohl, 2001) lassen sich für den eLearning Bereich drei Anforderungsniveaus beschreiben (Mayer et al., 2009):

- **Aufgaben zur Übung/Reproduktion:** Ziel ist die Festigung des Gelernten, der vertraute Umgang mit mathematischen Verfahren, aber auch Einüben des Umgangs mit Maßeinheiten, Größen, Syntax und Fachsprache. Aufgaben auf diesem Anforderungsniveau sind wenig komplex und adressieren idealerweise nur ein Themengebiet, z. B. das Auflösen einer Gleichung mit Hilfe der pq-Formel.

- **Aufgaben auf dem Niveau Anwenden und Verstehen:** Ziel ist das Erlangen eines tieferen Verständnisses mathematischer Problemstellungen, das Herstellen von Bezügen zwischen mathematischen Verfahren, sowie zwischen mathematischen Verfahren und „authentischen" Problemen. Beispiele für Aufgaben auf diesem Niveau sind Textaufgaben, kleinere Herleitungen oder Beweise.
- **Problemlösen:** Ziel ist das Anwenden und Kombinieren mathematischer Verfahren in unterschiedlichen Kontexten. Problemlöseaufgaben zeichnen sich durch hohe Komplexität (und Bearbeitungsdauer) und offene Lösungsansätze aus.

Für die Selbstdiagnose zu Beginn und die Lernerfolgskontrolle am Ende des Vorkurses (Pre-Posttest Vergleich) kommen ausschließlich Aufgaben von geringer Komplexität zum Einsatz, die in weniger als fünf Minuten gelöst werden sollten.

Nach Durchführung des Einstiegstests erhalten die Lernenden ein diagnostisches Feedback mit Hinweis auf geeignete Lernmodule, die kurze „aktivierende" Übungsaufgaben mit ansteigender Komplexität für das Selbststudium enthalten, für die auch technische oder ingenieurwissenschaftliche Themen als Anker genutzt werden können.

Aufgaben von hoher Komplexität sind eher für die Arbeit in Gruppen bzw. unter Anleitung geeignet, im Konzept für formatives eAssessment kommen sie daher nur in den Kursformaten zum Einsatz, die von Fach-Mentor/-innen betreut werden und den direkten Austausch über individuelle Lösungsansätze erlauben.

**Tab. 1: Einsatz von Aufgabentypen im formativen eAssessment**

| | Selbstdiagnose | Übung | Lernerfolgs-kontrolle |
|---|---|---|---|
| **Geringer Komplexitätsgrad**<br>Aufgabentypen: geschlossen und halb offen, Multiple Choice, numerische Eingabe | x | x | x |
| **Mittlerer Komplexitätsgrad**<br>Aufgabentypen: geschlossen und halb offen, Multiple Choice, numerische Eingabe, Formeleingabe (z. B. STACK, vgl. Sangwin, 2012) | | x | |
| **Hoher Komplexitätsgrad**<br>Aufgabentypen: offen, Upload von ausformulierten Lösungen, Feedback durch Fach-Mentor/innen | | x | |



## Beispiel

Im Lernmodul „Arithmetik" werden unter anderem Teilbarkeit und die Faktorisierung von ganzen Zahlen wiederholt. Im Online-Lernmodul wird dieses Thema durch ein sehr einfaches Beispiel eingeführt und mit einer Animation illustriert (s. Abb. 1). Im weiteren Verlauf des Lernmoduls erhalten die Lernenden ähnliche Übungsaufgaben mit etwas ansteigender Schwierigkeit. Diese Aufgaben decken die unteren Komplexitätsniveaus ab, im jeweiligen Fragefeedback wird eine umfassende Musterlösung angeboten.

Im betreuten eLearning wird zu diesem Lerninhalt eine „Einreichaufgabe" gestellt, die sich auf einem höheren Niveau befindet (s. Abb. 2). Hier können unterschiedliche Herangehensweisen ausprobiert und mit der/dem Betreuer/-in diskutiert werden. In der abschließenden (Online-) Diskussion werden dann unterschiedliche Ansätze vorgestellt.

## Evaluation

Insgesamt waren im Jahr 2014 603 angehende Studierende im Online-Vorkurs eingeschrieben, davon haben 132 am „Betreuten eLearning" teilgenommen. Fachliche Kompetenz, Vorwissen im Bereich mathematischer Grundlagen, wurde über den diagnostischen Eingangstest erfasst, der Lernerfolg im Vorkurs über einen Kontrolltest. Überfachliche Aspekte wurden über einen Fragebogen zum Lernverhalten adressiert (vgl. Schiefele et al., 2003), zusätzlich wurde die Online-Kommunikation im Vorkurs analysiert. Die Evaluationsfragebögen wurden insgesamt von 205 Teilnehmer/-innen beantwortet (davon 73 Teilnehmer/-innen Betreutes eLearning).

Der Einsatz der Einreichaufgaben wurde positiv evaluiert, 72 % der Teilnehmer/-innen bezeichneten diesen Aufgabentyp als „hilfreich" bzw. „sehr hilfreich". Ähnlich gutes Feedback erhielt die direkte E-Mail-Kommunikation mit den Fach-Mentor/-innen, während die Kommunikation über das Forum eher seltener genutzt wurde (s. Abb. 3).

**Abb. 1: Online-Aufgabe (niedrige Komplexität) zum Thema Teilbarkeit**

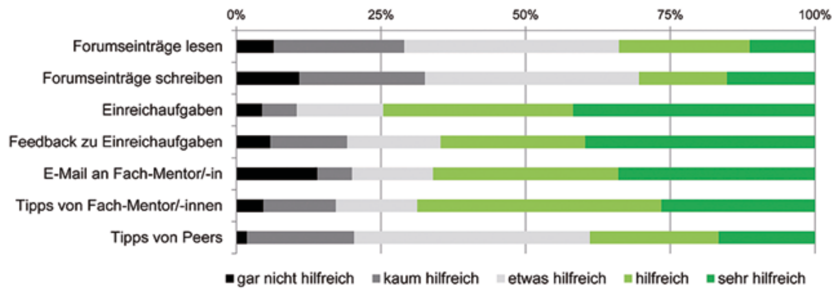

**Abb. 2: Einreich-Aufgabe (hohe Komplexität) zum Thema Teilbarkeit (zit. nach Bartholomé et al., 1995)**

Diese Aufgabe stammt aus einem indischen Rechenbuch des siebten Jahrhunderts:

Eine Frau trägt einen Korb mit Eiern auf dem Kopf. Als ein Pferd an ihr vorbei galoppiert, erschrickt sie und lässt den Korb fallen, so dass alle Eier zerbrechen. Als sie gefragt wird, wie viele Eier sie im Korb hatte, antwortet sie, dass sie das nicht wisse, weil sie nicht so weit zählen kann, dass aber, als sie die Eier in Gruppen von zweien aufteilte, eins übrigblieb, als sie die Eier in Gruppen von dreien aufteilte, zwei übrigblieben, als sie die Eier in Gruppen von vieren aufteilte, drei übrigblieben und als sie die Eier in Gruppen von fünfen aufteilte, vier übrigblieben

Wie viele Eier hatte sie im Korb?

**Abb. 3: Evaluationsfragebogen: „Welche Angebote des betreuten E-Learning waren für Sie hilfreich?“ (Skala von 1: gar nicht hilfreich bis 5: sehr hilfreich)(n=131; k. A. n=1)**




Aus den vorliegenden Daten lässt sich nur teilweise ein Zusammenhang zwischen fachlichen und überfachlichen Fähigkeiten ablesen. So wurde beispielsweise erwartet, dass kommunikative Fähigkeiten, also eine hohe Aktivität und Interaktion in Foren und mit den Fach-Mentor/-innen, mit guten und sehr guten fachlichen Leistungen einhergehen. Im Kurs „Betreutes eLearning“ waren allerdings lediglich 16 Teilnehmer/-innen deutlich aktiv, und diese hatten weder im diagnostischen Eingangstest noch im Abschlusstest signifikant bessere (oder schlechtere) Ergebnisse.

In Bezug auf das Lernverhalten lassen sich teilweise Zusammenhänge zwischen einem hohen Grad von Selbstregulation (z. B. „Ich habe das Lernpensum, das ich mir vorgenommen habe, immer geschafft“) und guten Testergebnissen aufzeigen. Die Zusammenhänge sind allerdings nicht für alle Items nachweisbar, und Interaktionen mit anderen Variablen, wie z. B. schulischer Hintergrund oder tatsächliche Lernaktivität auf der Plattform, müssen noch genauer untersucht werden. Wenig überraschend waren signifikante Unterschiede zwischen Teilnehmer/-innen mit Zertifikat (n=132) und Teilnehmer/-innen, die die Einreichaufgaben nicht abgegeben und das betreute eLearning abgebrochen haben (n=19).

Für den Jahrgang 2015 wird das betreute eLearning durch Lernmaterialien zum Thema Zeitmanagement, Stressmanagement und Lesetechniken ergänzt und eine zusätzliche didaktische Schulung der Fach-Mentor/-innen durchgeführt. Der Fragepool, der im Rahmen des optes Teilprojekts formatives eAssessment entwickelt wurde, kommt in den Vorkursen der Partnerhochschulen zum Einsatz und wird nach Abschluss der aktuellen Projektphase als offene Ressource bereitgestellt.



**Literatur**

Aebli, H. (2011): Zwölf Grundformen des Lehrens. Eine Allgemeine Didaktik auf psychologischer Grundlage. Medien und Inhalte didaktischer Kommunikation, der Lernzyklus. Stuttgart: Klett-Cotta.

Anderson, L. W. & Krathwohl, D. R. (2001): A taxonomy for learning, teaching, and assessing. A revision of Bloom's taxonomy of educational objectives. New York: Longman.

Bartholomé, A., Rung, J. & Kern, H. (1995): Zahlentheorie für Einsteiger. Braunschweig: Vieweg.

Boekaerts, M., Pintrich, P. R. & Zeidner, M. (Hrsg.) (2000): Handbook of self-regulation. New York: Academic Press.

Croft, A. C., Harrison, M. C. & Robinson, C. L. (2009): Recruitment and retention of students – an integrated and holistic vision of mathematics support. International Journal of Mathematical Education in Science and Technology, 40 (1), 109–125.

Deimling, E. (2012): Betreuter Onlinekurs Mathematik zur Vorbereitung auf das Studium www.dhbw-mosbach.de/mediendidaktik.

Derr, K., Hübl, R. & Podgayetskaya, T. (2015): Betreuungsangebote in einem Online Vorkurs Mathematik: Modularisierung als Antwort auf heterogene Studierendenschaft? In: Gesellschaft für Didaktik der Mathematik GDM (Hrsg.), Beiträge zum Mathematikunterricht.

Halm, L., Heubach, M., Mersch, A. & Wrenger, B. (2013): Zwei Seiten des Online-Lernens in mathematischen Grundlagenveranstaltungen: Unterstützung Lehrender und Betreuung Studierender im Selbststudium, Tagungsband zum 1. HD MINT Symposium, S. 177–183.

Hoppenbrock, A., Schreiber, S., Göller, R., Biehler, R., Büchler, B., Hochmuth, R. & Rück, H.-G. (Hrsg.) (2013): Mathematik im Übergang Schule/Hochschule und im ersten Studienjahr. khdm report 2013.

Mayer, H. O., Hertnagel, J. & Weber, H. (Hrsg.) (2009): Lernzielüberprüfung im eLearning. München: Oldenbourg.

Sangwin, C. (2012): Computer Aided Assessment of Mathematics using Stack, 12th International Congress on Mathematical Education COEX .

Schiefele, U., Streblow, L., Ermgassen, U. & Moschner, B. (2003): Lernmotivation und Lernstrategien als Bedingungen der Studienleistung. Ergebnisse einer Längsschnittstudie. Zeitschrift für Pädagogische Psychologie, 17 (3–4), 185–198.

Schiefele, U. & Wild, K.P. (1994) Lernstrategien im Studium: Ergebnisse zur Faktorenstruktur und Reliabilität eines neuen Fragebogens. *Zeitschrift für Differentielle und Diagnostische Psychologie, 15*(4), 185–200.

Wolf, P. & Biehler, R. (2014). Entwicklung und Erprobung anwendungsorientierter Aufgaben für Ingenieurstudienanfänger/innen. *Zeitschrift für Hochschulentwicklung, 9*(4), 169–190.

Zimmerman, B.J. (1989). Models of self-regulated learning and academic achievement. In B.J. Zimmerman & D.H. Schunk (Hrsg.), *Self-regulated learning and academic achievement: Theory, research and practice* (S. 1–26). New York: Springer.

A.9 Derr, K.; Hübl, R.; Podgayetskaya, T. (2015). “Online support in a pre-course in mathematics: approaches to addressing heterogenic groups” (Original title: Betreuungsangebote in einem Online Vorkurs Mathematik: Modularisierung als Antwort auf heterogene Studierendenschaft?). In: F. Caluori, H. Linneweber-Lammerskitten and C. Streit (eds.): Beiträge zum Mathematikunterricht, WTM, Münster, pp. 228–231.

DOI: https://doi.org/10.17877/de290r-16618

https://eldorado.tu-dortmund.de/bitstream/2003/34565/1/BzMU15_Derr_OnlineVorkurs.pdf

Katja DERR, Reinhold HÜBL, Tatyana PODGAYETSKAYA, Mannheim

# Betreuungsangebote in einem Online Vorkurs Mathematik: Modularisierung als Antwort auf heterogene Studierendenschaft?

## 1. Einleitung

Im BMBF-geförderten Verbund-Projekt „optes - Optimierung der Selbststudiumsphase“ werden Methoden und Konzepte zum Einsatz computergestützter Vorkurse in Mathematik entwickelt. Studienanfänger/-innen der Ingenieurwissenschaften sollen dabei möglichst früh angeregt werden, ihr Grundlagenwissen in Mathematik zu testen und gegebenenfalls aufzufrischen.

Eine Herausforderung bei der Gestaltung von Vor- und Brückenkursen stellen die ungleichen Ausgangsvoraussetzungen der Teilnehmer/-innen dar; nicht nur ihre Vorkenntnisse in Mathematik unterscheiden sich teilweise erheblich, auch die Fähigkeit zum selbstgesteuerten Lernen ist sehr unterschiedlich ausgeprägt (Baumert et al., 2000; Biehler et al., 2012). Um diese heterogene Gruppe zu adressieren werden im optes Projekt verschiedene didaktische und technische Maßnahmen angeboten und evaluiert. Im optes Teilprojekt „formatives eAssessment“, das an der Dualen Hochschule Baden-Württemberg Mannheim angesiedelt ist, wurde für den Jahrgang 2014/15 ein modulares Vorkursangebot erprobt. Zusätzlich zum Selbststudium auf der Online Plattform konnten angehende Studierende einen einwöchigen Präsenzkurs und / oder einen einmonatigen Kurs „betreutes eLearning“ belegen.

## 2. Konzept

Das Programm zur Studienvorbereitung beginnt mit einem umfassenden diagnostischen Online-Selbsttest, der zehn mathematische Themengebiete abdeckt und auf dem Mindestanforderungskatalog der Arbeitsgruppe „cooperation schule:hochschule“ (cosh, 2014) basiert.

Nach Abgabe des Tests erhalten die Teilnehmer/-innen ein Feedback mit Gesamtpunktzahl, einen allgemeinen Text zur Interpretationshilfe sowie eine Auswertung nach den zehn mathematischen Kategorien. Bei Bedarf wird eine Empfehlung ausgesprochen, dieses Thema zu bearbeiten. Hierzu werden Online-Lernmodule zur Verfügung gestellt, die bis zum Studienbeginn bearbeitet werden können. Zur Erfassung des Lernerfolgs wird in der ersten Woche nach Studienbeginn in den PC-Räumen der Hochschule ein zweiter Test durchgeführt. Dieser enthält Aufgaben, die vom Schwierigkeitsgrad mit denen des Einstiegstest vergleichbar sind und die gleichen mathematischen Grundlagenthemen abdecken.

Dieses Basis-Angebot steht allen angehenden Studierenden der Fakultät Technik zur Verfügung und wurde in den Jahren 2011 bis 2014 sukzessive auf- und ausgebaut. Neben der Analyse und schrittweisen Verbesserung der Qualität der Pre- und Post-Tests wurde die jährliche Evaluation dazu genutzt das didaktische Konzept anzupassen und zu optimieren. So werden seit 2012 einwöchige Präsenzkurse für Studienanfänger/-innen mit Fachhochschulreife angeboten, da diese Gruppe die niedrigsten Einstiegstestergebnisse (und auch den geringsten Lernzuwachs) erzielt hatte. Angesichts wachsender Nachfrage nach Unterstützung bei der Studienvorbereitung wurden diese Präsenzkurse für alle Studienanfänger geöffnet und das Angebot durch einen einmonatigen Kurs „betreutes eLearning“ erweitert. Das Konzept basiert auf der Arbeit des optes Teilprojekts eMentoring (Halm et al., 2013), sowie auf Erfahrungen der DHBW Mosbach, die einen ähnlichen Ansatz verfolgt (Deimling, 2012).

Die angehenden Studierenden können sich selbst für den Kurs anmelden und werden auf Basis ihrer Einstiegstestergebnisse einer Gruppe zugeordnet, die ähnliche Ergebnisse pro Themengebiet erzielt hat (und dann die gleichen Lernmodule bearbeitet). Die Kommunikation zwischen den Teilnehmer/-innen läuft über themenspezifische Foren, Fragen können von Dozent/-innen oder Peers beantwortet werden.

Neben der stärkeren Strukturierung des Lernplans und Kommunikation in der Gruppe besteht der zentrale Unterschied zum Selbststudium in einer höheren Verbindlichkeit. Die Kursteilnahme wird nur bestätigt, wenn ein Teilnehmer vier Aufgabenblätter rechtzeitig bearbeitet und eingereicht hat (ein Aufgabenblatt pro Thema und Woche). Dieses offene Aufgabenformat ermöglicht den Dozent/-innen einen Einblick in die einzelnen Rechenschritte der Teilnehmer/-innen; anders als bei geschlossenen oder halb offenen Online-Aufgabentypen kann so nachvollzogen werden, ob und an welcher Stelle eines Lösungsansatzes eine Fehlkonzeption vorliegt.

## 3. Teilnehmerdaten

Insgesamt liegen Einstiegs- und Kontrolltestdaten für gut 80 Prozent der Studienanfänger/-innen der Fakultät Technik vor (603 von 722), außerdem Fragebogendaten wie Alter, Bundesland, schulischer Hintergrund oder Mathematiknoten der letzten Schuljahre. Die sechs einwöchigen Präsenzkurse wurden im Zeitraum August bis November durchgeführt (n=119); der vierwöchige Kurs „betreutes eLearning“ fand im September 2014 mit 132 Teilnehmer/-innen, verteilt auf elf Gruppen, statt.

In H. Linneweber-Lammerskitten (Hrsg.), *Beiträge zum Mathematikunterricht 2015* (S. x–y). Münster: WTM-Verlag

## 4. Ergebnisse

Im Einstiegstest wurden durchschnittlich 50% der Punkte erreicht, wobei die Ergebnisse eine starke Streuung aufweisen (Minimum: 7 %; Maximum: 93 %; Standardabweichung: 16,0). Im Hinblick auf die gewählte Lernform liegt der Mittelwert der Gruppe, die *kein* Zusatzangebot gewählt hat, etwas über diesem Durchschnitt (MW Einstiegstest: 52,4%; n=386). Die Teilnehmer/-innen an einem (oder beiden) Zusatzangebot(en) erzielten einen Mittelwert von 44,9% (n=217). Es haben sich also vor allem Studienanfänger/-innen mit schwächerem Einstiegstestergebnis für die Teilnahme an einem Zusatzangebot entschieden, wobei die Präsenzkurse von Studienanfänger/-innen mit Fachhochschulreife bevorzugt wurden. Angehende Studierende mit allgemeiner Hochschulreife (Gymnasium) waren dagegen stärker im Kurs „Betreutes eLearning“ vertreten.

Betrachtet man den Unterschied zwischen Einstiegs-und Kontrolltest, so konnte insgesamt eine Steigerung auf 55 % festgestellt werden. Die Teilnehmer/-innen, die den Kurs „Betreutes eLearning“ mit Zertifikat abgeschlossen haben (n=85), haben sich von durchschnittlich 47,5% im Einstiegstest auf 54,2% im Kontrolltest verbessert. Im Vergleich dazu ist der Lernerfolg der Präsenzkursteilnehmer (n=91) mit einer Verbesserung von 43,7% auf 47,3% geringer. Den stärksten Anstieg von 44,2% auf 53,3% verzeichneten die 28 Lernenden, die an beiden Kursformen teilgenommen haben.

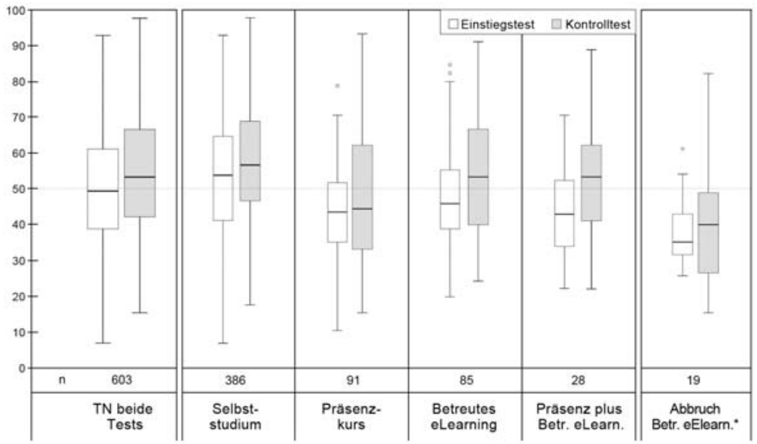



**Abbildung: Boxplots der Einstiegs- und Kontrolltestergebnisse 2014 insgesamt (n=603) und in den unterschiedlichen Lernformen Selbststudium, Präsenzkurs und Betreutes eLearning (*in dieser Gruppe sind 6 Teilnehmer enthalten, die danach am Präsenzkurs teilgenommen haben)**

## 5. Fazit

Der Ansatz, die sehr heterogene Gruppe der Studienanfänger/-innen durch ein modulares Angebot zu adressieren, hat sich bewährt. Während Studienanfänger/-innen mit gutem und sehr gutem Einstiegstestergebnis kleinere Wissenslücken im Selbststudium schließen konnten, wurden insbesondere Studienanfänger/-innen mit schwächeren Einstiegstestergebnissen zur Teilnahme an den Zusatzangeboten motiviert.

Das Kursangebot „betreutes eLearning“ hat dabei zu einem deutlich besseren Lernerfolg geführt als der Präsenzkurs. Dieses Ergebnis ist in erster Linie konzeptionell begründet, da über Abgabe und Korrektur von Übungen eine stärkere Verbindlichkeit hergestellt wurde. Durch die Kursdauer von einen Monat wurden außerdem längere Übungsphasen ermöglicht. Studienanfänger/-innen, die über die Teilnahme am einwöchigen Präsenzkurs hinaus keine weiteren Lernaktivitäten unternommen haben, haben im Mittel nur einen geringen Lernzuwachs gezeigt. Die Gruppe, die das betreute eLearning abgebrochen hat (n=19), hatte im Einstiegstest (MW: 38,0%) und im Kontrolltest (MW: 39,9%) ein unterdurchschnittliches Ergebnis und konnte ganz offenbar kaum von dem Angebot profitieren.

Beim Vergleich der Kursformen ist zu berücksichtigen, dass die Vorkenntnisse der Teilnehmer/-innen an der eLearning Variante durchschnittlich etwas besser waren als die der Präsenzkursteilnehmer/-innen. Dieser größere Abstand ist durch einen einwöchigen Kurs offensichtlich nicht zu schließen, und so haben Studienanfänger/-innen, die sich für beide Kursangebote entschieden haben, auch den größten Lernzuwachs zu verzeichnen.

### Literatur


Baumert, J., Klieme, E., Neubrand, M., Prenzel, M., Schiefele, U., Schneider, W., Tillmann, K.-J. & Weiß, M. (2000). *Fähigkeit zum selbstregulierten Lernen als fächerübergreifende Kompetenz*. Berlin: Max-Planck-Institut für Bildungsforschung.

Biehler, R., Fischer, P. R., Hochmuth, R. & Wassong, T. (2012). Self-regulated learning and self assessment in online mathematics bridging courses. In: Juan et al. (Hrsg.), *Teaching Mathematics Online: Emergent Technologies and Methodologies* (S. 216–237). Hershey, PA: IGI Global.

cosh cooperation schule:hochschule (2014). *Mindestanforderungskatalog Mathematik (2.0) der Hochschulen Baden-Württembergs für ein Studium von WiMINT-Fächern.* www.mathematik-schule-hochschule.de.

Deimling, E. (2012). *Betreuter Onlinekurs Mathematik zur Vorbereitung auf das Studium* www.dhbw-mosbach.de/mediendidaktik.

Halm, L., Heubach, M., Mersch, A. & Wrenger, B. (2013). Zwei Seiten des Online-Lernens in mathematischen Grundlagenveranstaltungen: Unterstützung Lehrender und Betreuung Studierender im Selbststudium, *Tagungsband zum 1. HD MINT Symposium* (S. 177–183).

A.10 Derr, K.; Hübl, R. (2014) “Online pre-courses in mathematics” (Original title: Mathematik Studienvorbereitung Online für technische Studiengänge). In P. Morschheuser (ed.) Qualifizierung von Studierenden im Student-Life-Cycle, Proceedings Mosbacher Tag der Lehre, 23rd October 2015, Mosbach, pp. 104-109

# Mathematik Studienvorbereitung Online für technische Studiengänge

Katja Derr, Reinhold Hübl

DHBW Mannheim

## 1 Einleitung

Viele Studienanfänger sind nicht ausreichend auf die Anforderungen eines ingenieurwissenschaftlichen Studiums vorbereitet, insbesondere in Mathematik bestehen teilweise erhebliche Defizite, die parallel zum Studium nur schwer aufgeholt werden können (SEFI mathematics working group, 2002; Schwenk/Berger, 2006; In der Smitten/Heublein, 2013). Vor - bzw. Brückenkurse haben hier die Aufgabe, Grundlagenwissen aufzufrischen und auf die Hochschulmathematik einzustimmen. Zunehmend kommen dabei Online- oder Blended Learning Angebote zum Einsatz, die die Lebenssituation der angehenden Studierenden, ihre Lernpräferenzen und differierenden fachlichen Vorkenntnisse stärker berücksichtigen können (Fischer/Biehler, 2011; Krumke et al., 2012; Bausch et al., 2014).

Am DHBW-Standort Mannheim wurde im Wintersemester 2010 mit dem Aufbau eines Online-gestützten Studienvorbereitungsprogramms Mathematik begonnen, das seither sukzessive erweitert und auf Basis der jährlichen Evaluation optimiert wurde. Ziel ist es, ein möglichst flexibles und modulares Angebot für die sehr heterogene Gruppe der angehenden Studierenden zu entwickeln. Viele Schulabsolventen haben kleinere Wissenslücken, die problemlos im Selbststudium geschlossen werden können, andere sind mit großen Defiziten im Grundlagenbereich konfrontiert und /oder verfügen nicht über angemessene Lernstrategien. Für diese Gruppe werden zusätzliche Unterstützungsangebote erprobt und ausgewertet.

Durch die Mitarbeit im Verbundprojekt optes[18] wurde 2012 darüber hinaus mit der Entwicklung eines umfassenden Fragepools zum Thema Grundlagenmathematik begonnen, der nach Abschluss des Projekts als offene Ressource allen interessierten Hochschulen zur Verfügung steht. Im vorliegenden Beitrag wird das Konzept der Studienvorbereitung Mathematik am Standort Mannheim vorgestellt und die Ergebnisse der Jahrgänge 2011 bis 2013 im Hinblick auf den weiteren Ausbau der Lernplattform zusammengefasst.

Für die Evaluation wurde das Teilnehmerfeedback über Fragebögen erfasst. 2012 und 2013 wurden außerdem Gruppeninterviews mit Studienanfängern durchgeführt, um eine umfassendere Rückmeldung zu erhalten und die Qualität der Fragebögen zu verbessern. Da der schulische Hintergrund als Prädiktor für

[18] optes ist ein Verbundprojekt der Dualen Hochschule Baden-Württemberg, der Hochschule Ostwestfalen-Lippe und des ILIAS open source e-Learning e.V. in Zusammenarbeit mit der Helmut-Schmidt-Universität Hamburg sowie der Zeppelin Universität Friedrichshafen





fachliches Wissen sowie Lernerfolg in Frage kommt (Akey, 2006, Polaczek/Henn, 2008, Henn/Polaczek, 2007), wurden personenbezogene Daten wie Alter, Geschlecht, Art der Schulausbildung sowie Schulnoten erhoben und in Bezug auf das Ergebnis im Pre- und Posttest analysiert.

## 2 Projektübersicht

Schon die ersten Projektevaluationen haben gezeigt, dass Studienanfänger oftmals unsicher sind, ob ihre Mathematik-Kenntnisse für das Ingenieursstudium ausreichen. Das Online-Programm beginnt darum mit einem umfassenden diagnostischen Selbsttest, der die Lerninhalte des Vorkurses abdeckt und die Lernenden unterstützt, ihre Kenntnisse in diesen Bereichen zu überprüfen. Das Feedback beinhaltet Lernempfehlungen und Links zu zehn interaktiven Lernmodulen der Propädeutik: 1) Arithmetik, 2) Gleichungen, 3) Potenzen, Wurzeln und Logarithmen, 4) Funktionen, 5) Geometrie, 6) Trigonometrie, 7) Logik und Kombinatorik, 8) Reelle Zahlen, 9) Vektoren und lineare Algebra und 10) Grenzwerte und Stetigkeit. Die ersten sechs Lernmodule umfassen ausschließlich Inhalte der gymnasialen Mittel- und Oberstufe und wurden mit dem Vorschlag eines gemeinsamen Mathematik-Curriculums der „cosh"- Gruppe abgestimmt, das als Referenz für Lehrer und Hochschuldozenten in Baden-Württemberg dient (Dürrschnabel et al., 2013). Die Teilnehmer werden darauf hingewiesen, diese Inhalte zuerst zu bearbeiten. Die Inhalte der letzten vier Lernmodule können nicht bei allen angehenden Studierenden als Vorwissen vorausgesetzt werden und weisen teilweise schon Bezüge zum Studium auf; ihre Bearbeitung ist optional.

Die Lernmodule enthalten viele Übungsaufgaben und thematischen Kurztests und können im Selbststudium bearbeitet werden. Ferner werden einwöchige Präsenzkurse angeboten und im Jahr 2014 erstmals ein einmonatiger eLearning-Kurs, der von Fachdozenten betreut wird.

Zum Abschluss der Studienvorbereitung / Beginn des Studiums wird in der ersten Vorlesungswoche in den Computerräumen der Hochschule ein Test zur Lernerfolgskontrolle durchgeführt. Auf Basis der Kontrolltestergebnisse können sich die Studienanfänger dann für den Besuch von studienbegleitenden Mathematiktutorien entscheiden.

## 3 Test- und Evaluationsergebnisse

Im Jahr 2013 nahmen 83% der Studienanfänger am diagnostischen Eingangstest teil (617 von 745), auch in 2011 und 2012 waren es ca. 80%. Am Kontrolltest in der ersten Semesterwoche nahmen fast alle Studienanfänger der Fakultät Technik teil.

Im diagnostischen Eingangstest wurden in allen drei Jahren im Durchschnitt etwa 50% der Aufgaben korrekt gelöst. Es ist allerdings anzumerken, dass der Test auf Basis der Evaluationen zweimal überarbeitet wurde, so wurden etwa auffällig schwere Aufgaben geändert bzw. ersetzt; die Anzahl der Aufgaben wurde von 90 auf 77 verringert, so dass der Test in 2013 insgesamt leichter war als in den Vorjahren. Charakteristisch ist die große Heterogenität der Ergebnisse, in 2013 lag der Minimalwert bei 10% und das Maximum bei 95% richtig beantworteter Fragen (Standardabweichung: 16,5).

In Abbildung 1 ist zu sehen, dass ein Viertel der Teilnehmer 2013 ein gutes bis sehr gutes Ergebnis erzielt hat (mit mehr als 60% richtiger Lösungen), während die Hälfte der Eingangstestteilnehmer sich im Bereich zwischen 40 und 60% befindet. Ein Viertel der Teilnehmer (154) hat ein Ergebnis unter 40% erzielt (mit dem Minimalwert von 10% richtiger Antworten).

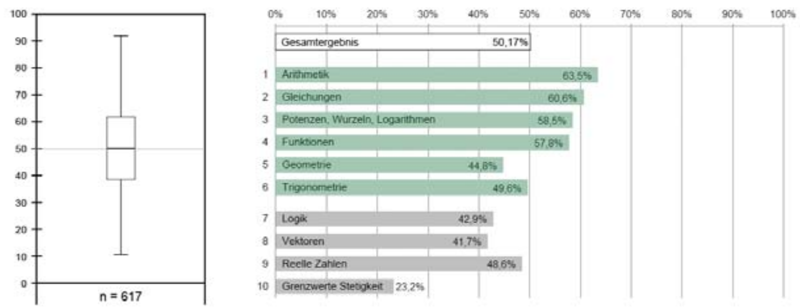



Abbildung 1: Boxplot Eingangstestergebnis 2013 in Prozent, alle Teilnehmer, plus Ergebnisse nach mathematischen Kategorien in Prozent

Die Auswertung nach mathematischen Kategorien zeigt, dass in allen Themengebieten Defizite bestehen, wobei die ersten vier der Kernthemen noch deutlich besser abschneiden als die Kategorien Geometrie und Trigonometrie, ganz zu schweigen von den vier Themengebieten Logik, Vektoren, Reelle Zahlen, Grenzwerte und Stetigkeit.

## 3.1 Ergebnisse im diagnostischen Eingangstest nach Teilnehmergruppen

Der Frauenanteil lag durchschnittlich bei 13%, dies entspricht dem Geschlechterverhältnis in vergleichbaren Ingenieursstudiengängen in Deutschland (Autorengruppe Bildungsberichterstattung, 2012). Die Mittelwerte der Frauen im diagnostischen Eingangstest waren in allen drei Jahren etwas niedriger als die der Männer, der Unterschied ist jedoch nicht signifikant.

Anders sieht es bei der Art der Hochschulzugangsberechtigung aus. Die Studienanfänger an der DHBW kommen „traditionell" direkt von der Schule (Gymnasium), seit der Öffnung des Studiums für Absolventen mit Fachhochschulreife in 2009 sind aber auch zunehmend Studienanfänger mit anderen Lebensläufen oder mit beruflicher Qualifizierung vertreten. Etwa 15% der Studienanfänger in der Technik haben das Abitur an einem beruflichen Gymnasium erworben, ca. 11% kommen mit Fachhochschulreife an die DHBW Mannheim. Beruflich qualifizierte Studienanfänger sind mit 1% bislang die Ausnahme, Abiturienten von allgemeinen Gymnasien sind mit mehr als 70% deutlich in der Überzahl. Diese Gruppe hatte mit ca. 57% in 2013 (2012: 51%; 2011: 56%) ein signifikant besseres Testergebnis als Absolventen von beruflichen Gymnasien oder Studienanfänger mit Fachhochschulreife (p < .001)(siehe Abbildung 2).





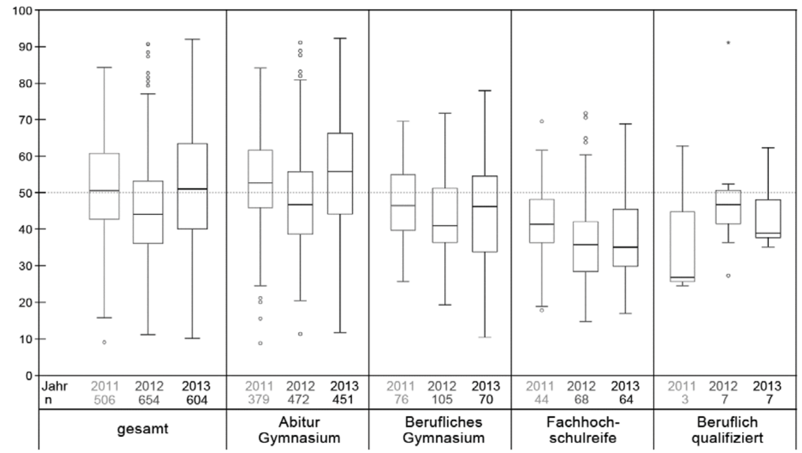



Abbildung 2: Eingangstestergebnis 2011, 2012, 2013 in Prozent, Vergleich der Art der Hochschulzugangsberechtigung (Datenbasis: Teilnehmer an beiden Tests)

Einschränkend ist zu sagen, dass die Ergebnisse in allen Untergruppen stark streuen, insbesondere in der größten Gruppe der Abiturienten Gymnasium. Auch die schulbezogenen Variablen „Note im Abschlusszeugnis" und „Mathematik-Schulnote" haben einen signifikanten Einfluss auf das Ergebnis im diagnostischen Eingangstest (p bei beiden Variablen < .001). Auch hier sind die Gruppen ungleich verteilt, vor allem bei der Mathematiknote gab die Mehrheit der Studienanfänger an, dass sie gute bzw. sehr gute Mathematiknoten in der Schule hatten („sehr gut": 26-28%, „gut": 50-53%). Nimmt man die Art der Hochschulzugangsberechtigung in das Modell auf, führt das zu einer deutlicheren Trennschärfe, doch auch in der stärksten Gruppe der Abiturienten mit sehr guten Noten werden noch relativ häufig Ergebnisse unter dem Durchschnittswert erzielt.

Als möglicher Einflussfaktor wurde die Einführung des achtjährigen Gymnasiums untersucht. Die DHBW Mannheim ist Einzugsgebiet für die Bundesländer Baden-Württemberg (ca. 25% der Studienanfänger, Einführung von G8 in 2012), Rheinland-Pfalz (21%, kein G8) und Hessen (19%, G8 seit 2013). Mit 11% der Studienanfänger kommt eine weitere relevante Gruppe aus Nordrhein-Westfalen (G8 seit 2013). Für die Eingangstestergebnisse der vier Länder wurde 2013 eine Varianzanalyse durchgeführt. Es konnte kein signifikanter Unterschied zwischen G8- und G9- Absolventen nachgewiesen werden, weder insgesamt noch auf Länderebene. Auffällig war in allen drei Jahren ein relativ schwaches Ergebnis für die Abiturienten aus Baden-Württemberg, dies allerdings unabhängig von G8 oder G9.

## 3.2 Nutzung des Lernangebots

Die interaktiven Lernmodule wurden in allen drei Jahren von über 70% der Teilnehmer genutzt. Das Lernverhalten der Studienanfänger orientierte sich dabei häufig weniger an den ausgesprochenen Lernempfehlungen als an der Reihenfolge der Lernmodule auf der Lernplattform. So werden die Zugriffszahlen nach einer anfänglich hohen Nutzung beim Lernmodul „Arithmetik" sukzessive weniger. Das diagnostische Feedback wurde angesichts dieser Befunde überarbeitet, doch auch im Jahr 2013 war dieses Lernverhalten zu beobachten. Möglicherweise bevorzugen viele Lernende den Einstieg über ein leichter zugängliches Thema wie Arithmetik, auch wenn sie hierfür keine explizite Lernempfehlung erhalten haben.

Vergleicht man die Pre- und Post-Testergebnisse, haben sich die Studienanfänger, die auch den Eingangstest gemacht haben, im Kontrolltest im Mittel um fünf Prozentpunkte verbessert (Mittelwert Eingangstest 2013: 50,26; Kontrolltest: 55,06; Mittelwert der Teilnehmer, die nicht an Studienvorbereitung teilgenommen haben: 49,26). Dieses insgesamt positive Ergebnis ist zu differenzieren, da auch diese Daten erhebliche Streuung aufweisen.

Etwa die Hälfte der Teilnehmer hat sich um mehr als fünf Prozentpunkte verbessert (mit einem Maximalwert von plus 48), dies waren vor allem Teilnehmer mit schwächerem Eingangstestergebnis und einer dementsprechend höheren Anzahl von Lernempfehlungen. 20% der Teilnehmer haben sich allerdings im zweiten Test verschlechtert (Minimalwert: -35), diese Gruppe besteht vor allem aus Teilnehmern, die im ersten Test gut oder sehr gut abgeschnitten haben. Ein Grund für die Verschlechterung könnte sein, dass leistungsstarke Studienanfänger im Kontrolltest „taktisch" agiert haben und bewusst ein schlechtes Ergebnis erzielt, um an einem mathematischen Tutorium teilnehmen zu können. Auch eine gewisse „Testmüdigkeit" könnte eine Rolle spielen. Ein dritter Ansatz für das Nachlassen der Teilnehmer mit eher gutem Eingangstestergebnis findet sich in der Theorie des „Expertise Reversal Effects", die besagt, dass Teilnehmer mit guten Vorwissen von einem Lernprogramm, das ihre Kenntnisse nochmals und/oder anders erklärt, eher verunsichert als gefördert werden können (Kalyuga et al., 2003). Auf Basis der vorliegenden Daten ist dieser Effekt allerdings nicht nachweis- oder widerlegbar.

# 4 Fazit und Ausblick

Die Datenanalyse hat gezeigt, dass bekannte Prädiktoren wie Art der Hochschulzugangsberechtigung, Note im Abschlusszeugnis oder Note im Mathematik einen starken Zusammenhang mit dem Eingangstestergebnis aufweisen. Einschränkend ist zu bemerken, dass in den genannten Variablen starke Unterschiede in den Gruppengrößen bestehen (Abiturienten von Gymnasien und gute Noten sind in der Überzahl), und dass trotz der signifikanten Ergebnisse die Daten innerhalb der einzelnen Gruppen stark streuen.

Die hohe Heterogenität der Studienanfänger stellt ein Hauptproblem bei der Gestaltung adäquater Vorkursangebote dar, dies betrifft sowohl das fachliche Vorwissen als auch die Fähigkeit zum selbstregulierten Lernen. Auch wenn durch den diagnostischen Eingangstest Problembewusstsein geweckt





werden konnte, das in vielen Fällen zu Lernaktivitäten und Wissenszuwachs geführt hat, besteht im Bereich Aktivierung und länger anhaltender Motivation der Teilnehmer noch Optimierungsbedarf.

Für die Studienanfänger des Jahrgangs 2014/15 wurden die Betreuungsangebote im Vorkurs durch einwöchige Präsenzkurse sowie den Online-Kurs „Betreutes eLearning" erweitert. Auf Basis der Daten des aktuellen Jahrgangs im Vergleich mit den Jahrgängen 2011- 2013 wird untersucht werden, welche Unterstützungsangebote für welche Studierendengruppen geeignet sind.

# 5 Literaturverzeichnis


Akey, T.M. (2006): School context, student attitudes and behavior, academic achievement. An exploratory analysis, mdrc publications, 2006

Autorengruppe Bildungsberichterstattung (2012): Bildung in Deutschland 2012. Ein indikatorengestützter Bericht mit einer Analyse zur kulturellen Bildung im Lebenslauf, Bielefeld, 2012

Bausch, I. et al. (2014), Mathematische Vor- und Brückenkurse. Konzepte und Studien zur Hochschuldidaktik und Lehrerbildung Mathematik, , Wiesbaden: Springer, 2014

Dürrschnabel, K. et al. (2013): Mindestanforderungskatalog Mathematik der Hochschulen Baden-Württembergs für ein Studium von MINT oder Wirtschaftsfächern (WiMINT): Ergebnis einer Fachtagung am 5. Juli 2012 in Esslingen

Fischer, P.R./Biehler, R. (2011): Über die Heterogenität unserer Studienanfänger. Ergebnisse einer empirischen Untersuchung von Teilnehmern mathematischer Vorkurse. Tagungsband der Gesellschaft für Didaktik der Mathematik GDM 2011, Freiburg, 2011

Henn, G./ Polaczek, C. (2007): Studienerfolg in den Ingenieurwissenschaften", Das Hochschulwesen, Vol. 55 No. 5, S.144–147

In der Smitten, S./Heublein, U. (2013): Qualitätsmanagement zur Vorbeugung von Studienabbrüchen", Zeitschrift für Hochschulentwicklung, Vol. 8 No. 2, S.98–109

Kalyuga, S./Ayres, P./Chandler, P./Sweller, J. (2003): The Expertise Reversal Effect. In: Educational Psychologist 38 (1), S. 23–31

Krumke, S.O./Roegner, K. /Schüler, L. /Seiler, R. /Stens, R. (2012): Der Online-Mathematik Brückenkurs OMB. Eine Chance zur Lösung der Probleme an der Schnittstelle Schule/Hochschule. DMV Mitteilungen Juni 2012

Polaczek, C./Henn, G. (2008): Vergleichende Auswertung des Mathematik-Eingangstests. http://www.fh-aachen.de/uploads/media/Eingangstest_WS_07_08.pdf

Schwenk, A./Berger, M. (2006): Zwischen Wunsch und Wirklichkeit: Was können unsere Studienanfänger?, Die Neue Hochschule No. 2, S. 36–40

SEFI mathematics working group (2002): Mathematics for the european engineer. A curriculum for the twenty-first century, Bruxelles, 2002

A.11 Derr, K.; Hübl, R. (2013) “Self-study university preparation in mathematics: didactical aspects of self-assessment” (Original title: Mathematik-Studienvorbereitung im Selbststudium: Didaktische Aspekte des Selbst-Assessment). Proceedings 1st HD-MINT-Symposium, 7-8 November 2013, Nuremberg, pp. 138-143.

ISSN: 1612-4537

https://www.th-nuernberg.de/fileadmin/abteilungen/sll/Dokumente/Publikationen-Fachartikel_PDFs/HD_MINT_Tagungsband_2013.pdf

# Mathematik-Studienvorbereitung im Selbststudium: Didaktische Aspekte des Selbst-Assessment

Katja Derr, Reinhold Hübl; DHBW Mannheim

## Einleitung

Statistische Untersuchungen zur Entwicklung der Studienanfängerzahlen in den Ingenieurswissenschaften sind meist verbunden mit einem Hinweis auf die steigende Zahl der Studierenden, die ihr MINT-Studium nicht beenden (z. B. Autorengruppe Bildungsberichterstattung, 2012). Die Gründe hierfür sind vielfältig, häufig sind zu hohe Leistungsanforderungen bzw. nicht bestandene Zwischen- und Abschlussprüfungen ausschlaggebend (Heublein et al., 2009). Eingangstestergebnisse sowie hohe Durchfallquoten in Mathematik-Klausuren im ersten und zweiten Semester weisen darauf hin, dass viele Studienanfänger/-innen nicht ausreichend auf die mathematischen Anforderungen eines ingenieurwissenschaftlichen Studiums vorbereitet sind. Auch die Fähigkeit der Studierenden zur Selbsteinschätzung und zur Bewertung des eigenen Kenntnisstands ist sehr unterschiedlich ausgeprägt, so dass oft erst im Studienverlauf grundlegende Defizite erkannt werden. Im Zuge der Öffnung der Hochschulen für Schulabgänger/-innen aus unterschiedlichen Bildungswegen ist eine wachsende Differenzierung in Bezug auf ihre Grundkenntnisse zu beobachten (z. B. Biehler u. Fischer, 2011), was die Konzeption und Durchführung von Vor- bzw. Brückenkursen in Mathematik erschwert.

Für das BMBF-geförderte Verbund-Projekt „optes – Optimierung der Selbststudiumsphase" wird im Teilprojekt ‚formatives Assessment' an der Entwicklung von online gestützten Selbsttests in Mathematik gearbeitet. Ziele von optes sind die Reduzierung der Heterogenität im mathematischen Grundlagenwissen von Studienanfängern, der Ausbau finanzierbarer Konzepte zur verbesserten Begleitung des Selbststudiums sowie die Verringerung der Abbruchquoten in den MINT-Fächern.

Angehende Studierende sollen möglichst früh zur Beschäftigung mit ggf. bestehenden mathematischen Defiziten angeregt werden. Durch formatives e-Assessment erhalten sie Hilfsmittel zur Selbstdiagnose, zur Strukturierung des eigenen Lernprozesses und zur Lernerfolgskontrolle. Die Arbeit mit online-gestützten Selbstlernmaterialien ist zentraler Bestandteil des optes-Konzepts, so dass technischen Komponenten wie automatischer Testauswertung oder elektronisch generiertem Feedback große Bedeutung zukommt. Im Folgenden wird das dem Teilprojekt zugrunde liegende theoretische Konzept von „Formativem eAssessment" erläutert, die Rolle des Feedback in interaktiven Umgebungen diskutiert und auf die Vorteile, Nachteile und technischen Probleme bei der Gestaltung von Online-Aufgaben eingegangen.



## Formatives Assessment

In der angelsächsischen Literatur findet sich der Begriff Assessment im Zusammenhang mit allen Formen der Leistungserhebung, wobei zwischen summativen Assessments, die Eingang in eine Gesamtbewertung (Note) finden, und formativen Assessments in Form von Übungen, Selbsttests oder Gruppenarbeiten unterschieden wird (vgl. Sadler, 1989; Black u. Wiliam, 1998). Formatives Assessment vermittelt Lehrenden und Lernenden einen Überblick über den aktuellen Lernstand einer Gruppe oder eines Individuums. Es lässt sich als Prozess beschreiben, der dem summativen Assessment vorgeschaltet ist und „alle Formen von Leistungsbeurteilung" umfasst, „die Informationen über die Diskrepanz zwischen Lernzielen und aktuellem Lernstand liefern und dadurch den Lehrenden und/oder den Lernenden selbst helfen, den weiteren Lernprozess zu gestalten" (Klieme et al., 2010, S. 64–65) .

Bislang wurden die Vorteile der Implementierung von formativem Assessment vor allem im Schul-Kontext und als Mittel der Unterrichtsgestaltung beschrieben (Black u. William, 1998). Die beiden zentralen Funktionen des formativen Assessment sind, eine Lücke (‚gap') zwischen dem Lernziel und dem aktuellen Lernstand sichtbar zu machen und dann Handlungsmöglichkeiten zum Schließen dieser Lücke aufzuzeigen. Im Unterrichtsverlauf kann ein Verständnisproblem lange unbemerkt bleiben, und die Lücke wird weder dem Lernenden noch dem Lehrenden bewusst. Der Fokus beim formativen Assessment liegt daher auf der Herstellung eines „kognitiven Konflikts" (Black u. Wiliam, 2009, S. 19), der dann zeitnah bearbeitet werden kann, bevor weitere Lerninhalte hinzukommen oder das fehlerhafte Verständnis im summativen Assessment zu Tage tritt.

Der Einsatz von Übungsaufgaben im Unterricht hat eine aktivierende Funktion, insbesondere, wenn die Lernenden im Rahmen von Peer- oder Selbst-Assessments auch die Ergebniskontrolle übernehmen. Untersuchungen zum Zusammenhang zwischen Selbst-Evaluation und Lernerfolg weisen darauf hin, dass Selbst-Assessments sich positiv auf die Selbstwirksamkeitserfahrung auswirken („self-efficacy") und, insbesondere bei erwachsenen Lernenden, Motivation und Selbststeuerung fördern können (Schunk u. Ertmer, 1999, S. 252).

## Formatives eAssessment

Selbsttests sind fester Bestandteil von E-Learning Programmen, und bei Lernenden beliebt, da das Feedback zeitnah erfolgt und die Teilnehmer/-innen über Zeitpunkt und Anzahl der Wiederholungen selbst entscheiden können (Whitelock, 2008; Heidenreich, 2009). Da die Lernenden mehr Verantwortung für die Gestaltung des Lernprozesses erhalten, ermöglicht und fördert formatives eAssessment die Fähigkeit zum selbstgesteuerten Lernen (Nicol u. Macfarlane-Dick, 2006).

Indem die Teilnehmer/-innen zu „partners in learning" (Heritage, 2007, p. 145) gemacht werden, wachsen die meta-kognitiven Anforderungen, da ihnen die Interpretation des Testergebnisses sowie die Entscheidung über anschließende Lernhandlungen übertragen werden. Dieser „cognitive load“ (z. B. Sweller, 2005) sollte so niedrig wie möglich gehalten werden, damit die Lernenden sich auf die Lerninhalte konzentrieren können. Dies erfordert eine übersichtliche und nachvollziehbare Struktur des Lernprogramms sowie aussagekräftige Formen des Feedback.

## Feedback

Teilnehmer sollen über das Feedback auf eine Aufgabe oder eine Aufgabensammlung in die Lage versetzt werden, ihre Wissenslücke bzw. ihren Verständnis- oder Flüchtigkeitsfehler zu erkennen, um dann über daran anschließende Lernhandlungen zu entscheiden. „Gutes Feedback“ (Nicol u. Macfarlane-Dick, 2006) beinhaltet Meta-Informationen über Hintergrund und Ziele des Assessments sowie Hilfestellungen zur Interpretation des Ergebnisses. Mögliche Inhalte eines Feedback auf eine Online gestellte Aufgabe sind:

1. Richtig / Falsch (Verifikationsfeedback)(Renkl, 1991)
2. Lösung (erwartete Antwort)
3. Musterlösung bzw. Lösungsweg
4. Kommentar: z. B. Interpretationsvorschläge zu einem Fehler oder Lernempfehlungen, Links zu weiteren Aufgaben
5. Bewertung

Damit die Analyse des Feedback nicht zu viel kognitive Last (und Zeit) bindet, ist bei der Gestaltung des Programms zu entscheiden, welche dieser Informationen die Lernenden zu welchem Zeitpunkt des Lernprozesses benötigen. Im optes Projekt wird unterschieden zwischen diagnostischem Feedback auf Tests, die zur Erfassung des Lernstandes zu Beginn oder zum Abschluss des Lernprozesses stehen und formativem Feedback, das sich auf die Bearbeitung von einzelnen Übungsaufgaben bezieht.

### Diagnostisches Feedback

Zu Beginn des Lernprozesses steht die Orientierung im System im Vordergrund, die Teilnehmer/-innen benötigen Informationen über Sinn und Ziel der Lernaktivitäten, über die Lerninhalte, und natürlich darüber, ob sie in einem oder mehreren dieser Themen überhaupt Nachholbedarf haben (vgl. Lawson, 2003). Der Lernprozess wird darum über einen diagnostischen Eingangstest initiiert. Auf der Basis des Testergebnisses erhalten die Teilnehmer eine Bewertung pro Themengebiet, außerdem Kommentare in Form von Lernempfehlungen und Links zu den entsprechenden Lerninhalten. Zum Abschluss des Lernprozesses wird ein diagnostischer Abschlusstest durchgeführt, der in anonymisierter Form auch zur Evaluation des Projekts dient.



### Formatives Feedback

Während des Lernprozesses werden immer wieder Übungsaufgaben angeboten, um das gerade Gelernte anzuwenden. Das formative Feedback auf eine Übungsaufgabe besteht aus Verifikationsfeedback (richtig / falsch), der erwarteten Antwort, einer Musterlösung plus ggf. ein aufgabenspezifisches Feedback (z. B. Hinweise auf mögliche Rechenfehler oder Links zu weiteren Aufgaben).

Weitere Ansatzpunkte zur aktivierenden und motivierenden Gestaltung formativer eAssessments finden sich auf der Ebene der Aufgabengestaltung.

### Aufgabengestaltung

Die gängigen Autorentools für Tests, die in modernen Lernmanagementsystemen verfügbar sind, bieten unterschiedliche Fragetypen an, die mehr oder weniger gut für die Erstellung von Mathematik-Aufgaben geeignet sind.

Am gebräuchlichsten sind wohl Single- bzw. Multiple-Choice-Aufgaben, bei denen die Teilnehmer/-innen aus einer Liste vorgegebener Antworten eine bzw. mehrere richtige Antwort(en) auswählen. Dieser Fragetyp kam schon lange vor E-Learning zu Einsatz und wurde immer wieder kritisiert (z. B. Hoffmann, 1962), da durch die Auswahl vorgegebener Antworten eher „Wiedererkennung und logische Auswahlverfahren als Konstruktion und Verständnis geprüft werden“ (Craven, 2009). Mittlerweile finden sich in der Literatur viele Hinweise darauf, dass Multiple Choice Items zu qualitativ vergleichbaren Testergebnissen führen, wenn sie entsprechend gestaltet sind (z. B. Martinez, 1999).

Will man auf vorgegebene Antworten verzichten, ist auch die Eingabe der Antwort in ein Textfeld möglich, allerdings mit der Einschränkung, dass nur numerische Werte (also ganze oder Dezimalzahlen) abgefragt werden können. Die Eingabe von Brüchen oder mathematischen Formeln ist nicht bzw. nur mit hohem technischem Aufwand auf Seiten der Hochschule und guten Syntax-Kenntnissen auf Seiten der Teilnehmer möglich. Im Rahmen des optes Projekts wird an der Implementierung solcher innovativen Aufgabentypen gearbeitet, allerdings wird noch zu diskutieren sein, an welcher Stelle im Lernprozess Aufgaben mit relativ hohen meta-kognitiven Anforderungen zum Einsatz kommen sollten.

Weitere verfügbare Fragetypen sind Zuordnungen per „Drag&Drop“, Anordnungen von Texten oder Bildern in einer vorgegebenen Reihenfolge, sowie die Markierung eines Bereichs auf einer Abbildung („Hotspot“ bzw. „Imagemap“). Da alle dieser Fragetypen auf einer vorgegebenen Anzahl falscher und richtiger Antworten bzw. Antwort-Kombinationen basieren, treffen auf sie die schon zu Multiple-Choice-Items genannten Pro- und Contra-Aspekte zu.

Besonders bei interaktiven Aufgabentypen wie „Drag&Drop“ oder „Imagemap“ sollte darauf geachtet werden, dass die technische Bedienung nicht vom Inhalt der Frage ablenkt. Auch einfache Formate wie Multiple-Choice oder numerische Eingabe können, bei entsprechender Aufgabengestaltung, für die Lernenden anregend sein, ohne den Frust durch Falscheingabe.

Um Missverständnisse bei der Aufgabenstellung und/oder der Eingabe der Antwort möglichst weitgehend auszuräumen, sollten Online-Aufgaben in jedem Fall von mehreren Personen Korrektur gelesen und in einem iterativen Prozess auf ihre Verständlichkeit hin getestet werden.

## Fazit

Im optes Projekt soll das aktivierende und motivierende Potential von formativem Assessment genutzt werden, um Selbstlernprozesse anzustoßen und aufrecht zu erhalten. Die geschieht über aussagekräftiges Feedback, das sich entweder auf die Gestaltung des Lernprozesses (diagnostisches Feedback) oder die Fehleranalyse (formatives Feedback) bezieht. Durch den Einsatz anregender und innovativer Aufgabenformate sollen zusätzliche motivationale Effekte erzielt werden.

Allerdings sollten auch die Grenzen dieser Interventionen im Blick behalten werden. Jede Erhöhung der Komplexität – in Bezug auf das Feedback oder auf die Aufgabengestaltung – kann zu einem Verlust der Konzentration auf das zentrale Anliegen, das Erlernen oder Wiederholen grundlegender mathematischer Fertigkeiten, führen. Auch die Realisierbarkeit an den beteiligten Hochschul-Standorten sollte im Blick bleiben, um Angebote zu entwickeln, die nachhaltigen Nutzen bringen und über mehrere Jahre eingesetzt werden können.

### Referenzen

Autorengruppe Bildungsberichterstattung (2012), Bildung in Deutschland 2012: Ein indikatorengestützter Bericht mit einer Analyse zur kulturellen Bildung im Lebenslauf, Bielefeld.

Biehler, R. u. Fischer, P. R. (2011), Über die Heterogenität unserer Studienanfänger. Ergebnisse einer empirischen Untersuchung von Teilnehmern mathematischer Vorkurse, Freiburg

Black, P. u. Wiliam, D. (1998), Assessment and classroom learning, Assessment in Education, Vol. 5 No. 1, S. 7–71

Black, P. u. Wiliam, D. (2009), Developing the theory of formative assessment, Educational Assessment, Evaluation and Accountability 21(1)

Craven, P. (2009), History and Challenges of e-assessment. The ‚Cambridge Approach' perspective – e-assessment research and development 1989 to 2009

Heidenreich, S. (2009), Pädagogische Anforderungen an das Lernhandeln im E-Learning: Dimensionen von Selbstlernkompetenz, Medienpädagogik und Mediendidaktik, Dr. Kovac, Hamburg

Heritage, M. (2007), Formative Assessment: What do teachers need to know and do? Phi Delta Kappan, Vol. 89 No. 2, S. 140–145

Heublein, U., Hutzsch, C., Schreiber, J., Sommer, D. u. Besuch, D. (2009), Ursachen des Studienabbruchs in Bachelor- und in herkömmlichen Studiengängen: Ergebnisse einer bundesweiten Befragung von Exmatrikulierten des Studienjahres 2007/08, Projektbericht HIS

Hoffmann, B. (1962), The tyranny of testing, Crowell-Collier, New York

Klieme, E., Bürgermeister, A., Harks, B., Blum, W., Leiß, D. u. Rakoczy, K. (2010), Leistungsbeurteilung und Kompetenzmodellierung im Mathematikunterricht. Projekt Co2CA, in Klieme, E., Leutner, D. u. Kenk, M. (Eds.), Kompetenzmodellierung, Beltz, Weinheim, Basel, S. 64–74

Lawson, D. (2003), Diagnostic testing for mathematics, LTSN MathsTEAM Project report

Martinez, M.E. (1999), Cognition and the Question of Test Item Format, Educational Psychologist, Vol. 34 No. 4, S. 207–218

Nicol, D.J. u. Macfarlane-Dick, D. (2006), Formative assessment and self-regulated learning: A model and seven principles of good feedback practice, Studies in Higher Education, Vol. 31 No. 2

Renkl, A. (1991), Die Bedeutung der Aufgaben- und Rückmeldungsgestaltung für die Leistungsentwicklung im Fach Mathematik, Dissertation, Universität Heidelberg, 1991

Sadler, R. (1989), Formative Assessment and the Design of Instructional Systems, Instructional Science, Vol. 18, S. 119–144

Schunk, D.H. u. Ertmer, P.A. (1999), Self-regulatory processes during computer skill acquisition: Goal and self-evaluative influences, Journal of Educational Psychology No. 91, S. 251–260

Sweller, J. (2005), Implications of cognitive load theory for multimedia learning, in Mayer, R.E. (Ed.), The Cambridge handbook of multimedia learning, Cambridge University Press, New York, S. 19–30

Whitelock, D.M. (2008), Accelerating the assessment agenda: thinking outside the black box

A.12 Derr, K.; Hübl, R.; Ahmed, M.Z. (2013). “Web-based tests and learning material for study-preparation in mathematics for engineering programmes” (Original title: Online–Selbsttests und -Lernmaterialien zur Studienvorbereitung Mathematik) 2nd khdm-conference Mathematik im Übergang Schule / Hochschule und im ersten Studienjahr, 20-23 February 2013, University of Paderborn.

https://kobra.bibliothek.uni-kassel.de/bitstream/urn:nbn:de:hebis:34-2013081343293/3/khdm_report_13_01.pdf

# Online-Eingangstests und Lernmaterialien zur Studienvorbereitung Mathematik in den Ingenieurwissenschaften

Derr, Katja[1]; Hübl, Reinhold[1]; Ahmed, Zaki[2]
[1]Duale Hochschule Baden-Württemberg Mannheim; [2]Plymouth University
katja.derr@dhbw-mannheim.de

*Abstract*
*Im Rahmen der Evaluation des Online-gestützten Brückenkurses der Fakultät Technik wurden Faktoranalysen auf Basis der diagnostischen Tests sowie Befragungen und Gruppeninterviews durchgeführt. Die Ergebnisse zeigen eine hohe Heterogenität der angehenden Studierenden, nicht nur in Bezug auf ihre mathematischen Grundkenntnisse sondern auch in Bezug auf verfügbare Lernstrategien und die Fähigkeit zum Selbststudium.*

## Einleitung

In den vergangenen Jahren hat das Interesse an technischen Studiengängen deutlich zugenommen, im Studienjahr 2011 stieg die Zahl der Studienanfänger/-innen in diesem Bereich sogar stärker an als in anderen Studienrichtungen. Gleichzeitig ist eine wachsende Differenzierung der Schulabgänger/-innen in Bezug auf ihre Grundkenntnisse zu beobachten, insbesondere im Bereich der Mathematik.

Um die angehenden Studierenden frühzeitig auf die Bedeutung der Mathematik für ein technisches Studium sowie möglicherweise bestehende Wissenslücken hinzuweisen, bietet die DHBW Mannheim einen Selbsttest an, der einige Monate vor Studienbeginn durchgeführt werden kann. Das Test-Feedback beinhaltet individuelle Lernempfehlungen sowie Links zu Lernmaterialien, die dann in der verbleibenden Zeit bearbeitet werden können. Abgeschlossen wird das Programm durch einen Kontrolltest zu Beginn des Studiums. Seit Projektstart 2010 wird das Angebot sukzessive auf- und ausgebaut, ab 2011 werden die Tests online durchgeführt.

## Eingangstest

Seit 2011 besteht der Eingangstest aus 90 Aufgaben und deckt zehn Themengebiete der Mittel- und Oberstufenmathematik ab. Jedes Thema ist durch mehrere Items repräsentiert, um den Einfluss von Flüchtigkeitsfehlern zu minimieren. Die Tests wurden außerdem einer umfassenden Itemanalyse unterzogen, die zur Ersetzung oder Anpassung einiger Aufgaben führte. 60 der Eingangstest-Items wurden in 2011 und 2012 unverändert eingesetzt, dieses Set diente als Basis für den Vergleich der beiden Jahrgänge.

In beiden Jahren nahmen ca. 80 Prozent der Studienanfänger/-innen der Fakultät Technik am Eingangstest teil (2012: n=676; 2011: n=521). Durchschnittlich erreichten die Teilnehmer in beiden Jahren etwa die Hälfte der Punktzahl (2012: 47%; 2011: 52%). Die Schul-Mathematiknote hatte den stärksten Einfluss auf das Testergebnis, wobei auch in der Gruppe mit sehr guten Noten die Ergebnisse stark streuten. Als weiterer starker Faktor ist die Art der Hochschulzugangsberechtigung zu nennen: Absolventen von Gymnasien erzielten deutlich höhere Mittelwerte als die von Fachgymnasien, die wiederum besser abschnitten als Studienanfänger/-innen mit Fachhochschulreife. Für weitere Faktoren wie Alter, Geschlecht, Bundesland oder gewählter Studiengang konnte kein statistisch signifikanter Zusammenhang mit den Testergebnissen festgestellt werden.

Beim direkten Vergleich der beiden Jahrgänge (60 unveränderte Items) schnitt der Jahrgang 2012 insgesamt etwas schlechter ab. Besonders ausgeprägt war die Differenz zwischen 2011 und 2012 bei den Teilnehmern aus Baden-Württemberg. Da in diesem Bundesland in 2012 die Umstellung von neun- auf achtjähriges Gymnasium erfolgt war, lag es nahe, die schwächeren Testergebnisse als Folge der Verkürzung der Oberstufe zu interpretieren. Tatsächlich ließ sich aber kein Unterschied zwischen G8 und G9 in Baden-Württemberg feststellen, d.h. beide Teilgruppen haben sich





gleichermaßen verschlechtert. Ob es sich hierbei um einen generellen Trend oder einen einmaligen Ausreißer handelt, werden erst die Ergebnisse der kommenden Jahre zeigen.

## Nutzung der Lernmodule und Kontrolltest

Die Lernmodule werden jeweils ab Juli online bereitgestellt und können als PDF-Skript heruntergeladen oder alternativ als Online-Lernmodul bearbeitet werden (2012 waren vier der zehn Lernmodule in der interaktiven Version verfügbar). Zu Beginn des Studiums wird in den PC-Laboren der Hochschule ein Kontrolltest durchgeführt, außerdem werden Daten zum Nutzerverhalten, zur Usability und zur Zufriedenheit mit dem Angebot über einen Evaluationsfragebogen erfasst. Um einen besseren Einblick in die Lernstrategien der angehenden Studierenden zu gewinnen, wurden 2012 zusätzlich vier Gruppeninterviews durchgeführt. Die Analyse der Daten ergab ein sehr heterogenes Bild in Bezug auf Art und Intensität der Nutzung sowie auf die Ergebnisveränderung zwischen erstem und zweitem Test:

Mehr als 80% der Teilnehmer gaben an, ein oder mehrere Lernmodule bearbeitet zu haben, allerdings wurden bei der Auswahl der Themen die Lernempfehlungen nur bedingt berücksichtigt. In Bezug auf Häufigkeit und Dauer der Lernaktivitäten unterschieden sich die Teilnehmer erheblich, was wiederum zu stark differierenden Kontrolltestergebnissen führte. Die stärkste Verbesserung zwischen Eingangstest und Kontrolltest war bei Teilnehmern zu beobachten, die ein weniger gutes Eingangstestergebnis hatten und dementsprechend viele Lernempfehlungen erhalten haben. In dieser Gruppe wiederum haben Studienanfänger/-innen mit guten Mathematik-Noten am stärksten von der Nutzung der Lernmodule profitiert und sich stärker verbessert als Teilnehmer, die keine Lernmodule bearbeitet haben.

Ein interessantes Phänomen zeigte sich in Bezug auf die E-Learning Elemente: Während eine Gruppe die interaktiven Module klar bevorzugte und bemängelte, dass nicht alle Lerninhalte in dieser Form zur Verfügung standen, war eine zweite Gruppe dem Lernen am Computer gegenüber generell skeptisch und nutzte ausschließlich ausgedruckte PDFs. Eine kleinere dritte Gruppe nutzte beides.

Die Ergebnisse machen deutlich, dass sich die Schulabgänger nicht nur in ihren mathematischen Vorkenntnissen sondern auch in ihrer Bereitschaft und Fähigkeit zum Selbststudium stark unterscheiden. Vor allem Studienanfänger/-innen mit großen Wissenslücken haben Probleme, diese im relativ kurzen Zeitraum im Selbststudium aufzuarbeiten. Zusätzliche Präsenzangebote für die Gruppe der Studierenden mit Fachhochschulreife, die durch ihren schulischen Werdegang bedingt besonders große Lücken im Vorwissen aufweist, wurden zwar gut angenommen, führten aber wiederum dazu, dass die Selbstlernangebote von dieser Gruppe weniger intensiv genutzt wurden.

Angesichts der hohen Heterogenität innerhalb der Zielgruppe ist es schwierig, aus den Daten eindeutige Maßnahmen zur Optimierung des Lernprogramms abzuleiten. Daher soll das Angebot in seiner Grundstruktur mit den drei Säulen PDF-Skripte, interaktive Angebote sowie Präsenzelemente im Jahr 2013 beibehalten, basierend auf Evaluation und Teilnehmerfeedback überarbeitet und gestrafft werden, um einen Mix zu finden, der für möglichst viele Studienanfänger passende Elemente bereithält.

Hinweis: Bei Interesse kann ein Zugang zum Portal eingerichtet werden, es genügt eine formlose E-Mail an: zemath@dhbw-mannheim.de

# Online tests and learning material for study-preparation in mathematics for Engineering courses

Derr, Katja[1]; Hübl, Reinhold[1]; Ahmed, Zaki[2]
[1]Duale Hochschule Baden-Württemberg Mannheim; [2]Plymouth University
katja.derr@dhbw-mannheim.de

Among German school graduates the interest in taking up courses in Engineering seems to rise: In 2011 the number of first-year Engineering students grew stronger than all other courses of studies. At the same time the diversity in the group of first-year students has been growing, especially in the field of mathematics.

In order to rise awareness for the importance of mathematics for any technical courses of studies, Baden-Wuerttemberg Cooperative State University Mannheim offers an online self-assessment that can be taken several months before the courses of study begin. The test-feedback comprises of individual learning recommendations plus links to learning material that can be worked through in the remaining time. The program is finished with a control-test to be taken during the first week at the University. Since project kick-off in 2010 the project is built and adapted successively. Since 2011 all tests are carried out online.

## Entry test

The 90 entry test items cover ten secondary school topics from arithmetic to vector geometry. Each topic is represented by several items, thus trying to minimise the influence of careless mistakes. Furthermore, in 2011 and 2012 an item analysis was performed on the test that lead to changes on or replacements of items that did not lead to consistent results. 60 entry test items stayed unchanged and have been used to compare the results of 2011 and 2012.

In both years about 80 percent of the first year students at the faculty of science took the entry test (2012: n=676; 2011: n=521). In both years the participants' mean scores were around 50 percent (2012: 47%; 2011: 52%). School grades in mathematics had the strongest influence on test results, but with high variation even in the group of students with very good math grades. Another strong factor is the type of secondary school the students graduated from. Graduates from German gymnasium leading to Abitur could reach much better means than those from 'Fachgymnasien' or students with 'Fachhochschulreife'. Factors like age, gender, origin or chosen course of studies did not reveal statistical significant relations to test results.

When comparing both cohorts (60 unchanged items) the group of 2012 did not performed as good as 2011. This effect was rather strong with participants from Baden-Wuerttemberg. As in this part of Germany there had been a major change in secondary school curricula (the timespan being cut down from 9 to 8 years) it was presumed that the week results stemmed from the curricular reduction. Eventually there could no difference be made between students form Baden-Wuerttemberg that had visited a 9year or an 8-year program, both groups had worsened similarly. If this might be a general trend or rather a coincidence can only be shown by watching the results of the upcoming years.

## Learning modules and control test

The learning modules were available online in July. They could either be downloaded as pdf-files or worked through online (in 2012 four out of ten learning modules were provided in the interactive version). At the beginning of the courses of studies the control test was performed in the university's computer labs. User data, feedback to usability and overall satisfaction were gathered via an online questionnaire. In order to get a better understanding of students' interests and learning strategies four group interviews were taken additionally in 2012. Data analysis revealed a very heterogeneous picture in terms of learning types, learning intensity and difference between first and second test:

More than 80% of the participants claimed to have worked with the given learning material, though the learning recommendations were only randomly accounted for (?) considered (?). Duration and frequency of learning periods differed considerably, thus leading to strongly varying control test results. The strongest improvement between entry test and control test could be stated with participants that had achieved a rather poor entry test result and, respectively, a high amount of learning recommendations. In this group students with good math grades could profit the most from the use of the learning material and improved stronger than participants that did not work with the learning modules.

An interesting phenomenon showed in the use of e-learning elements: while one group of participants clearly preferred working online with the interactive learning modules and complained that not all learning modules were available in this format, a second group claimed skepticism against computer learning and used printed pdfs only. A smaller third group used both.

The results make clear that secondary school graduates not only differ in their mathematical knowledge but in their willingness and ability for self-directed study. Especially first-year students with large knowledge gaps experience problems to close those gaps in the relatively short timespan between end of school and beginning of university studies. Additional face-to-face classes for those students with ‚Fachhochschulreife' had high acceptance rates, but lead to diminished use of the self-study program.

Looking at the high heterogeneity in the target group it appears to be very difficult to derive distinct measures from the data to optimize the program. Therefore it is planned to stick to the program with the three branches pdf-scripts, interactive learning modules plus face-to-face courses in 2013, based on evaluation data and participants' feedback it should be revised and adapted in order to find a mix that might offer enough help for as many students as possible.

For interested readers we would be glad to provide with a login to the learning platform. Please email to: zemath@dhbw-mannheim.de

A.13 Derr, K.; Hübl, R.; Ahmed, M.Z. (2012). "University preparation via self-e-assessment & self-study: first findings and implications from evaluating an e-learning-platform". Proceedings of ECEL 2012, 11th European Conference on e-learning, 26-27 October 2012, University of Groningen.

ISBN: 978-1-908272-74-4

http://www.proceedings.com/17683.html

**University preparation via Self-e-Assessment & Self-study: First findings and implications from evaluating an e-Learning-platform**

Katja Derr[1], Reinhold Hübl[1], Mohammed Zaki Ahmed[2]
[1]Baden-Wuerttemberg Cooperative State University Mannheim, Germany
[2]Plymouth University, United Kingdom
katja.derr@dhbw-mannheim.de
reinhold.huebl@dhbw-mannheim.de
m.ahmed@plymouth.ac.uk

Abstract: Over the last years numerous efforts have been made to interest German adolescents in picking up engineering studies. While these efforts are slowly beginning to show an effect (increasing number of first year students), drop-out rates in engineering are rising. Not all students are equally prepared for their courses of study and not all are aware of the relevance of basic skills in mathematics. Once university courses have started, it is very challenging to meet demands and at the same time close gaps in secondary school knowledge. Thus mathematics, though not being the main interest of future engineers, can become crucial for studying successfully.

In order to raise awareness to the importance of mathematics at an early state, Baden-Wuerttemberg Cooperative State University Mannheim offers an online self-assessment for prospective engineering students. It can be taken several months before the actual courses of studies begin, so that existing gaps in knowledge can be addressed in the remaining time. After completing the test students are provided with electronic feedback and, if applicable, forwarded to learning modules they can work on. Both self-assessment and learning material are structured and categorized in the same way, totalling ten mathematical subject areas. During the first week at university a second assessment is conducted and students that still have gaps in some mathematical areas are advised to visit additional tutorials. Along with the second assessment goes a questionnaire concerning the individual use of and satisfaction with the learning material.

The first data analysis revealed that participants not only differ in their range of knowledge, but also in their motivation and ability to learn self-directed. While nearly all students were highly motivated to self-assess, not all could keep up this motivation in the self-study process. Especially students with lower math grades at school, and therefore maybe less basic knowledge, often failed to improve while students with good school grades not only performed better in the first assessment but could improve much more between the first and second assessment.

The article summarizes the findings of both e-assessments and use of e-learning material and discusses questions that arose from the evaluation. Some of the findings were used to adjust the e-assessments' design and to optimize the learning material, others revealed the need of additional research. As the overall group is very heterogeneous and therefore difficult to address in their individual needs a main focus in the future course of the project will be on finding out more about the students' interests and learning objectives and how they might be fostered.

Keywords: e-Assessment, Self-Assessment, Self-Study, Mathematics, Engineering

## Glossary

DHBW: Duale Hochschule Baden-Württemberg (Baden-Wuerttemberg Cooperative State University). Students at this type of university are employed and spend 50% of their courses of study at their place of work. DHBW degrees are B.A. and B.Sc.

Abitur: secondary school degree that allows progression to university

Fachhochschulreife: secondary school degree that allows progression to universities of applied sciences and cooperative universities

Gymnasium: secondary school leading to 'Abitur'

Fachgymnasium: secondary school leading to 'Abitur' but focusing either on technical or economic subjects

Fachoberschule, Berufsfachschule: secondary schools leading to 'Fachhochschulreife'

## 1. Introduction / project background

The study preparation project described in this article was initiated in reaction to the growing diversity in first year students' basic knowledge. Coming from different secondary school systems with varying curricula, not all students enrolling in university courses have the same starting position. This applies especially in the 'MINT' fields (German acronym for 'Mathematik, Informatik, Naturwissenschaft, Technik', similar to the English 'STEM' for 'Science, Technology, Engineering, Mathematics'). Mathematical grounding is a prerequisite to understanding university mathematics, which in turn is necessary to successfully study in this area. While some undergraduates are prepared for these demands, others experience serious problems with secondary school mathematics. Many universities try to address this heterogeneous group by offering bridging courses in basic mathematics. These courses usually take place in summer, before the main courses of study begin.

DHBW Mannheim has been facing similar problems with undergraduates enrolling for engineering courses. Being a cooperative university and most students spending the summer on internships, preparatory courses had not yet been an option. Traditionally, students were asked to take an entry-test on their first day at university (paper and pencil). If the test results indicated major gaps students were advised to attend an additional tutorial. Though being helpful, the tutorials add to students' workload. As a result it was decided to provide online learning material several months before enrolment in order to reach students living and working abroad.

This learning material consisted of ten modules covering most basic issues (arithmetic, equations, powers, roots, logarithms, functions, geometry, trigonometry, vectors and linear algebra, logic, limits and continuity). These learning modules were provided either as pdf files that could be downloaded from the learning platform, or as e-Learning lessons (at that point three out of ten modules had been made accessible in the interactive version). As the prospective students were supposed to use this material self-directed, it was important to provide them with an assisting tool to make their own learning decisions.

Self-regulated learning is an important concept in higher education, though it might not yet be applied very often in the field of assessment (Nicol & Macfarlane-Dick, 2006). In this case, self-assessment was used to help participants decide where to start learning and what to focus on. The online study-preparation was initiated by a thorough self-assessment that lead to learning recommendations in the ten mathematical areas.

Online-self-assessment means easy access and immediate feedback for the students and is time-saving for test administration and evaluation. Furthermore, it appears to be widely accepted by students, in some cases even preferred to paper and pencil tests (cf. Jurecka, 2008, Whitelock, 2008). Though some studies suggest that items presented on computer tend to be more difficult or might disadvantage students with low computer familiarity (e.g. Bennett et al, 2008) most findings indicate that test performance is not influenced by the mode in which it is presented, and therefore "in general, the 'digital divide' does not apply" (Gershon & Bergstrom 2004, p.602).

The team at DHBW's faculty of Science had already derived knowledge in the field of online-testing from a project for secondary school students, offering short self-assessments on the internet using the Open Source platform Moodle (see www.mathx3.de). In 2010, a first version of the e-assessment was organised with 497 first-year engineering students at the university's computer labs. These experiences were incorporated in the development of the self-e-assessment conducted in 2011.

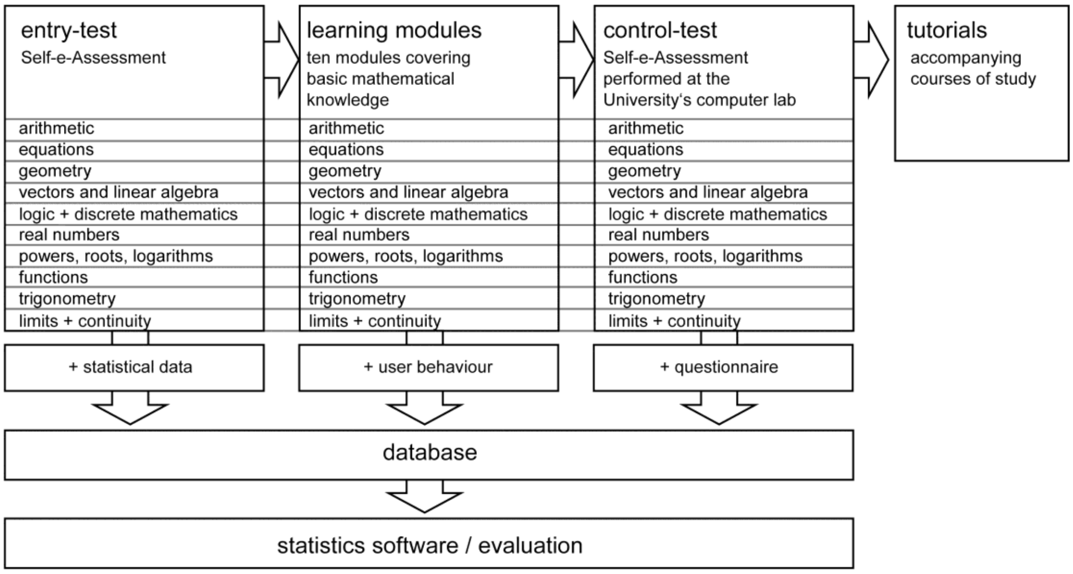



**Figure 1:** structure of e-assessments and e-learning platform

## 2. Description / Setting

### 2.1 Technical platform / architecture

The system is based on Open Source learning resource Moodle (version 2.2). The university's original Moodle system can only be used by enrolled students, therefore an extra system had to be installed for the study preparation course. For the self-assessment Moodle's 'quiz'-module was employed, for evaluation the 'questionnaire'-module and for learning content the 'lesson'-module. The design (theme) was changed according to the university's corporate design guidelines and some additional scripts were written to improve assessment feedback and usability. For participating in the assessment, an Internet browser and activation of both Javascript and Flash were required. Students were asked not to use any resource apart from scratch paper and the online calculator that went with the test.

Access to the system required registration, but all data were anonymised before evaluation. Participants were informed that their results and user data were confidential and would not be made known to teachers or employers. For analysis and evaluation all data were imported directly to the statistics software (in this case IBM SPSS).

### 2.2 Time and venue

The self-e-assessment (entry-test) could be taken from July until shortly before the second e-assessment (control-test) in October. Students were advised to take it at the office rather than at home, the presumption being that concentration might last longer in 'official' surroundings. Most companies were very supportive and provided participants with office time and space, some larger firms even organised corporate assessments with all of their prospective students in the companies' computer labs. Eventually 521 of 725 students took part in the entry-test, with about a third completing the test at home and the other two thirds at the office, either alone or with a group of peers.

*Note*: It was expected that students assessing at home would score best, being able to use graphic calculators or other resources, but actually the group doing the test at the office in a group with other students performed best (with these differences not being significant and the groups not differing in any of the collected variables, so far no conclusions were drawn from this result).

The control-test at the beginning of the courses of study was then completed by 99% of all first year students at the university's computer labs.

### 2.3 Sample

| | entry-test | control-test |
|---|---|---|
| number of participants | 521 | 718 |
| number of participants both tests | 506 | 506 |
| number of participants one test only | 15 | 212 |
| number of participants in evaluation / questionnaire | 503 | 503 |

**Table 1:** participants of 2011 study preparation and e-assessments

All test participants were prospective students of DHBW Mannheim's faculty of Science. With only 12% female students, the sample represented the usual gender relation in engineering. The course of study 'mechanical engineering' provided the largest group (n=161), followed by 'mechatronics' (n=116), 'computer science' (n=92), 'electrical engineering' (n=87) and industrial engineering (n=65).

75% of the sample had attended a secondary school (Gymnasium) leading to German 'Abitur' which allows progression to all German Universities. 15% had reached the 'Abitur' by attending a subject-related secondary school (Fach-Gymnasium, focused on either technical or economic subjects). The remaining 10% had attended schools leading to 'Fachhochschulreife', a certificate that allows studying at Universities of Applied Sciences only, or came from a professional field and had proved their ability to study in higher education by previously participating in another assessment.

In addition to the named statistical data students were asked about the grades achieved in their school diplomas and the grades they mostly had in school mathematics: 29% of the participants claimed that they had performed very good (A*/A) in mathematics, 51% good (A/B), 18% average (B/C) and 2% below average (D and lower).

### 2.4 Test Design

Both entry-test and control-test were designed to be similar in terms of content and difficulty, but the entry-test, being a complete self-e-assessment, had to provide students with a general overview of their basic knowledge. Therefore it was about twice as voluminous as the control-test. Participants could pace the time they needed to solve each single item, but the overall time was set. The entry-test, consisting of 90 items, had to be solved in 120 minutes, while the control-test ended after 60 minutes, consisting of 47 items. The Moodle quiz module offers a countdown that can be blended in alongside the test reminding the participants of how much time is left.

Both tests were structured by the above named ten mathematical areas, so that the entry-test consisted of approx. ten items per category, the control-test of five items per category.

*Difficulty of items*

All items were related to three levels of difficulty, 'easy', 'medium' and 'difficult'. Within the ten mathematical areas each level of difficulty was then represented, the 'medium' items summing up to about 50%. It was expected for 'easy' items to be solved by a majority while items claimed 'difficult' should lead to low scores. These predictions were then to be compared with the entry-test's and control-test's results.

*Type of items*

Though the use of formulae and mathematic notations is commonplace within paper and pencil examinations, it is not easily provided online. Entering Mathematical symbols requires online editing and / or basic knowledge of syntax which the students presumably did not have. It was therefore decided to offer numeric entry and multiple choice items only.

The use of multiple choice items is often discussed as being inferior to the range of items available in the 'classical' paper and pencil assessment, "…testing recognition and selection rather than construction and understanding" (Craven, 2009, p.4). Therefore the multiple choice items' results were to be analysed with a special regard to the factor of guessing and to be compared with the numeric entry items' results (see item analysis). The entry-test finally consisted of 54 multiple choice (mc) and 36 numeric entry items, the control-test of 36 mc and 24 numeric items.

| | entry-test | control-test |
|---|---|---|
| number of items in total | 90 | 47 |
| highest possible score* | 100 | 50 |
| set time | 120 min. | 60 min. |
| number of 'easy' items | 21 | 12 |
| number of 'medium' items | 44 | 27 |
| number of 'difficult' items | 25 | 8 |
| number of multiple choice items | 54 | 23 |
| number of numeric entry items | 36 | 24 |

**Table 2:** entry-test and control-test overview (*items with high complexity scored 2 points)

*Feedback*

After completing the test participants received an E-mail with their overall results and their results per mathematical area. Low scores in one or more areas lead to learning recommendations in these categories. It is planned to reuse both e-assessments throughout the project, so feedback did not include item solutions. The students were provided with links to the learning modules. On the Moodle platform they received further information on how to navigate the platform and make use of the given material.

## 3. Results

### 3.1 Overall results and item analysis

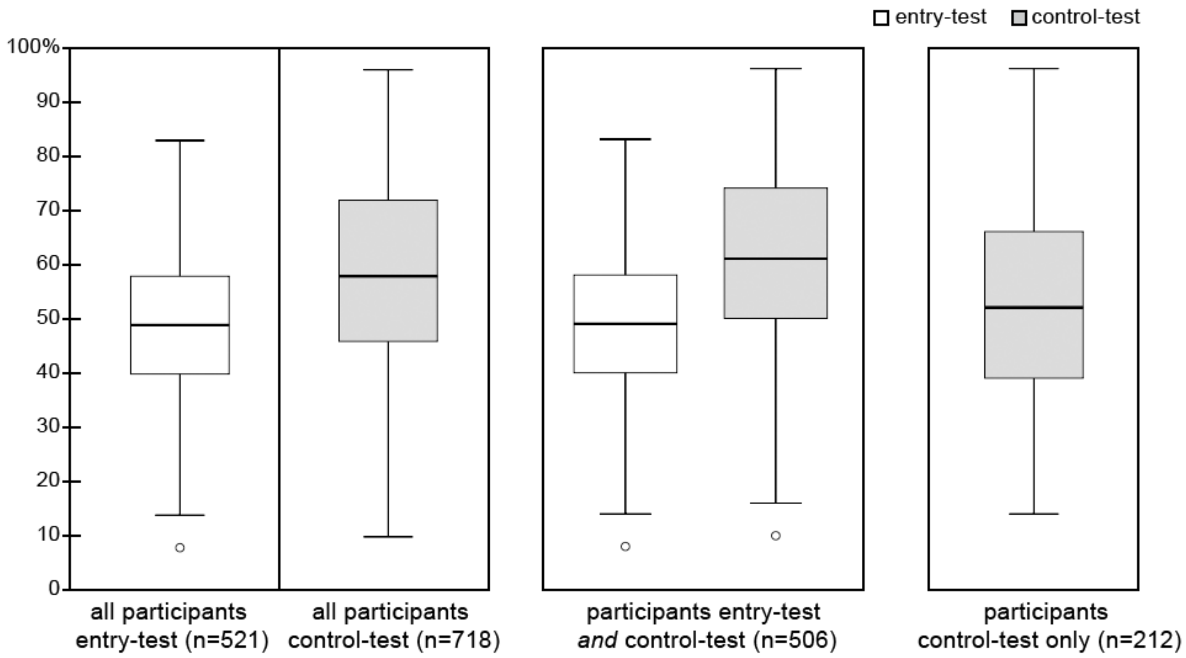
The 521 participants of the entry-test had an average score of 49.4. With the maximum being 83, the full score of 100 points was never reached. The best control-test score was 45 (out of 47), the mean of all 718 test participants was 29.3 or 58.7%.

A group of 212 students did not participate in the entry-test, in most cases because they had been enrolled by their employers only shortly before the courses of study began. The control-test thus being their first self-assessment, it was presumed that their results should be similar to those of the entry-test participants. With a mean of 52.8 this group actually scored a little better than the entry-test participants (49.4), but less than the students having completed both tests (n=506). This latter group had an average mean of 61.1 in the control-test.

It was derived from these overall results that the entry-test and control-test could be compared in terms of difficulty though the control-test appeared to be slightly easier than the entry-test (cf. figure 2). Via an item analysis both tests were then examined more thoroughly in order to adjust both tests' levels of difficulty and each single item's discrimination.

It was found that not all items had led to results matching their difficulty labels, thus to some extend leading to an imbalance between the tests' mathematical areas, e.g. in the categories 'arithmetic' which appeared to be too difficult compared to the control-test's similar category.

Both tests had been completed quite thoroughly by the participants; only three entry-test participants' results were excluded in the analysis because their test time was less than 60 minutes and they had not answered more than 50% of the given items. It was therefore noticeable that in two mathematical areas, 'vectors and linear algebra' and 'limits and continuity', some items were not answered at all by a large number of participants. This might indicate that some participants did not have any previous knowledge in these subjects and therefore skipped the items, an expected result with these categories being problematic issues in most basic mathematical exams.




| | entry-test (all participants) | control-test (all participants) | entry-test (participants who took both tests) | control-test (participants who took both tests) | control-test (participants who took control-test only) |
|---|---|---|---|---|---|
| n | 521 | 718 | 506 | 506 | 212 |
| Mean (%) | 49.37 | 58.69 | 49.36 | 61.14 | 52.83 |
| Median | 49.00 | 58.00 | 49.00 | 61.00 | 52.00 |
| standard deviation | 12.34 | 17.41 | 12.33 | 16.49 | 18.16 |
| minimum score | 8 | 10 | 8 | 10 | 14 |
| maximum score | 83 | 96 | 83 | 96 | 96 |

**Figure 2**: Test results (percentage) in entry-test and control test

As another aspect of the item analysis possible differences between the two types of items, mc and numeric entry, were investigated. Multiple choice items in both tests did not lead to better scores but their inter-item correlation and correlation with the overall result was lower, indicating a certain amount of guessing especially in the entry-test.

In any case, the item-total correlation of the entry-test's items was rather poor for both types of items, a finding that could not be explained satisfactorily. It might be assumed that the entry-test results were stronger influenced by motivational aspects, this first test being a self-assessment in most cases taken alone while the control-test was carried out on the university's premises, and therefore, maybe, with stronger efforts (the better results of the group taking the test with peers might also support this approach, see '2.2 Time and venue').

The mc items were offering one correct answer and 3-5 distractors (wrong choices). The number of distractors in both tests had no effect on the correlations or number of correct answers.

All findings from the item analysis were used to adjust the entry-test's and control-test's structure and level of difficulty for future test-versions. Finally, 16 entry-test items and 7 control-test items were replaced or adapted due to extreme scoring, mismatching the level of difficulty or to item-total correlation being too low. It also was discussed offering additional choices like 'I don't know the answer' in order to allow participants to communicate a lack of knowledge. Due to the poor results in the mathematical areas 'vectors and linear algebra' and 'limits and continuity' these two categories will in the future be labelled 'difficult' only.

### 3.2 Performance of different groups

In order to compare different groups and their development between entry-test and control-test, the results of both tests were standardised, the new mean being 100. All following results stem from the data of the participants having completed both tests (n=506).

It was found that most collected parameters like gender, state of origin or course of study, did not correlate with test results in a statistically significant way. There was, though, a rather strong relation between test results and mathematics grades during secondary education: Participants with excellent maths grades reached higher scores and showed the highest improvement between entry-test and control-test (entry-test score: 113.75; control-test score: 119.91). Participants with good to average math grades scored less in both tests and could not improve as much between both tests.

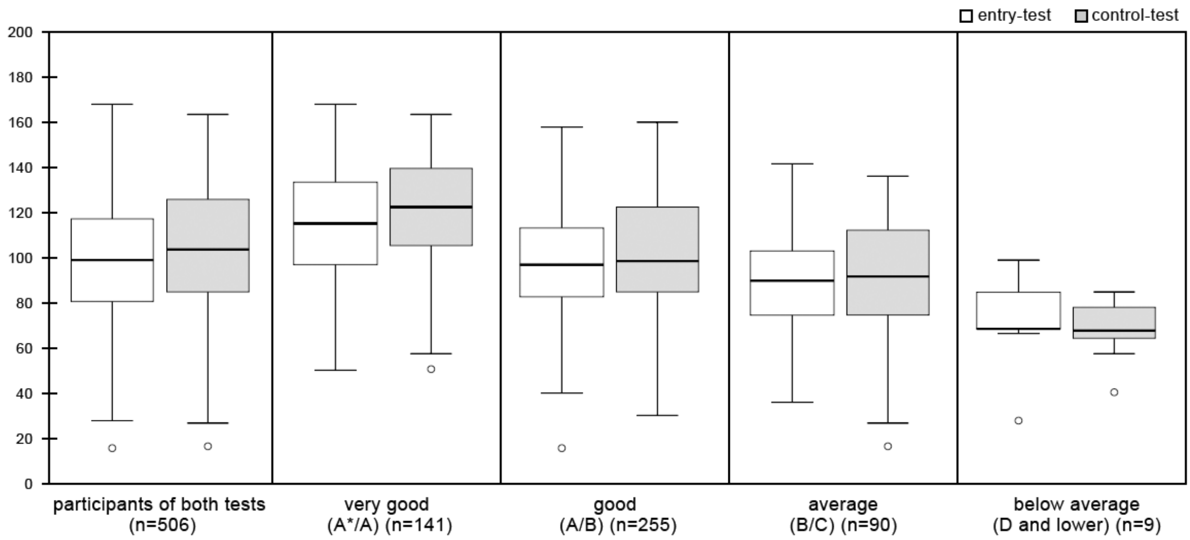



**Figure 3:** Test results in entry-test and control test: Mathematics grades at school (standardisation to new mean=100)

There was a significant relation between scores and type of secondary school graduation (type of diploma leading to university entrance level): Participants with the German ‘Abitur’ (n=457) obtained 101.94 points in the entry-test and 106.92 in the control-test while participants with ‘Fachhochschulreife’ (n=46) scored 81.80 in the entry-test and 78.85 in the control-test. Even though this group is rather small, the relation appears to be quite robust as it corresponds to the 2010 results.

### 3.3 Learning recommendations

All students that had participated in the entry-test received learning recommendations according to the ten basic mathematical areas. The recommendations were prioritised from being ‘highly recommended’, ‘recommended’ or ‘not necessary’, based on the results in each category. In most mathematical areas the results of similar assessments (e.g. entry-tests Aachen University of Applied Sciences; Henn, Polaczek, 2007) and our own findings of 2010 could be confirmed.

In the mathematical area ‘arithmetic’, for example, most items concerning percentage were answered correctly but items dealing with complex algebraic manipulations were only rarely solved which lead to a rather high recommendation rate in this category. Items in the category ‘linear and quadratic equations’ produced rather good results, the learning recommendations therefore were the lowest of this test, followed by ‘functions’ and ‘powers, roots, logarithms’. The categories ‘geometry’ and ‘trigonometry’ were less consistent: while most of the students showed basic geometrical knowledge, only few students could answer questions concerning trigonometric functions. For the mathematical area ‘limits and continuity’, being part of first years’ mathematics curriculum only the recommendations ‘not necessary’ or ‘recommended’ were given.

Figure 4 shows the number of recommendations for each learning module in relation to the number of students who actually worked through this learning module. (Note: these data were collected from the questionnaire, therefore might not in every case represent the individual use of learning material. A comparison with the users' entries in the database revealed some, but negligible differences between these two datasets. It was therefore decided to rely on the students' information.)

It was surprising that the degree of usage was, in a large number of cases, not related to the given recommendations. Not only did students ignore the difference between 'high' and 'neutral' recommendation, they also chose to work with learning modules they did not have any recommendations for. This applies to the first and second learning module especially, indicating that a majority decided to start 'from scratch' with the first learning module 'arithmetic', then working their way down the list and, eventually, losing motivation or simply running out of time.

It was also unexpected that the three interactive modules were not being used as frequently as the printed / pdf versions. Summarising, it can be stated that user behaviour in some cases did but in many cases did not refer to the entry-test's feedback and that further inquiries into the motivations and personal learning interests of this obviously heterogeneous group will be needed.

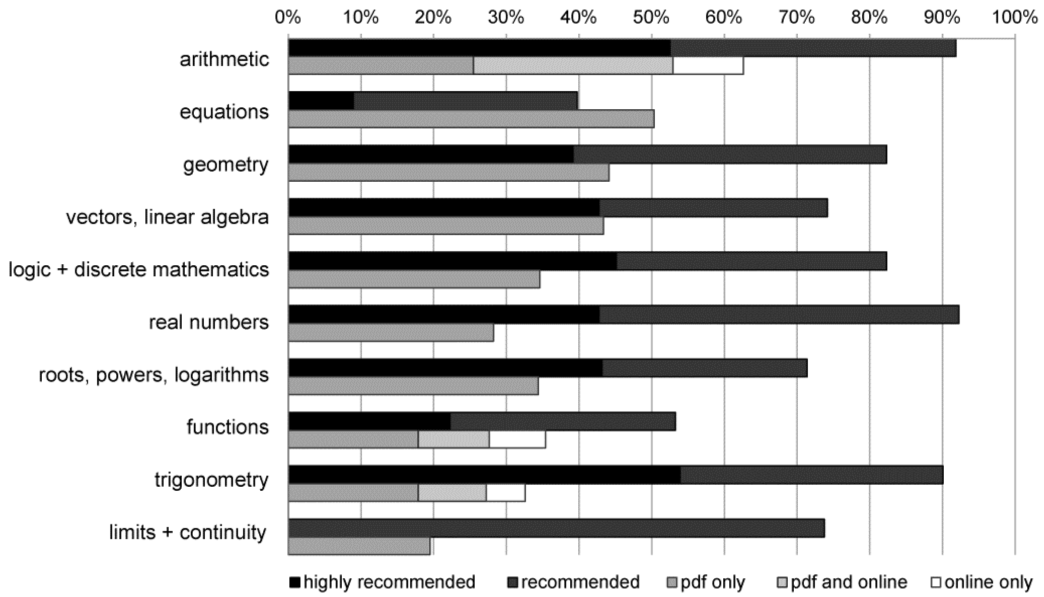



**Figure 4:** learning recommendations according to entry-test results.

It was then analysed how students that had worked with the given material did score in the second test in comparison to those who did not. Looking at the average scores, the 212 participants that took the control test only achieved a mean of 90.02, whereas the 506 participants that took both tests could improve from a mean of 99.96 in the entry-test to 104.18 in the control-test.

Students that claimed to have used at least one learning module had an average of 99.87 in the entry-test and an average of 104.31 in the control-test, whereas students that did not go through any learning modules improved their scores from 102.36 in the entry-test to 103.25 in the control-test. Students that claimed to have worked 7-10 learning modules even could improve from 99.8 to 107.6

These differences however are not statistically significant. Despite the overall improvement a clear connection between the use of learning modules and control-test scores could not be confirmed for all groups of participants and, correspondingly, all learning modules. The strongest improvement between entry-test and control-test was achieved by participants that scored poorly in the entry-test and therefore received a higher number of learning recommendations. In this group students with good math grades (n=141) could benefit the most from using the given learning modules, and therefore performed much better in the control-test than members of this group not having used any learning modules at all. This applies especially to the categories 'arithmetic', 'logic', 'powers, roots, logarithms' and 'functions'.

### 3.4 Evaluation

Before taking the control-test, all entry-test participants were asked to answer a questionnaire concerning their satisfaction with the self-e-assessment and the learning modules. The questions were answered via rating-scales from low to high agreement and free text entry additionally. 503 out of 506 entry-test participants answered the questionnaire.

The entry-test's level of difficulty was claimed being 'perfect' by a fifth of all participants, while the majority stated that the test was 'difficult' or 'diverging'. This result matched the item analysis that had revealed some entry-test items being too difficult in comparison to the control-test (cf. item analysis). Participants that had rated the entry-test 'difficult' or 'very difficult', reached lower average scores (mean 95.9 resp. 82.4) than participants that rated it 'perfect' or 'easy' (110.3 resp. 144.8). Participants with graduations other than 'Abitur' more often tended to judge the test as being difficult or very difficult (55.3% of this group's participants, in comparison 45.2% of participants with 'Abitur').

The evaluation also revealed that the test had contained several formulae and mathematical symbols not being familiar to the students. Nearly 90% of the test participants did not know one or more than one notation and a third of this group claimed not having known more than five expressions. The mean of this group was only 94.3 while participants without problems in understanding scored 102.9. In the control-test the differences between these groups were levelled out. Due to these results all items with possibly problematic expressions were replaced in order to provide participants from different schools with obviously differing curricula with equal chances.

78% of the test participants were comfortable with the test's usability, about 20% rated it 'medium'. There was no evidence, though, that satisfaction with usability had influenced the test result. There were some comments on the online flash calculator that went with the entry-test, mostly concerning dissatisfaction with the lack of features compared to 'normal' scientific calculators.

Satisfaction with technical aspects was also collected: 83% of the participants were able to conduct the assessment without disturbances, while 16% experienced minor problems. Test results of those participants that had reported problems (e.g. long waiting times for the database to answer) were less than average (mean = 95.7). Though this group did not have an especially high amount of non-answered items, the loss of time or feelings of uncertainty might have influenced their scores.

The satisfaction with the learning modules was very diverging, some modules like 'arithmetic' or 'powers, roots, logarithms' getting higher agreement than others (e.g. 'logic', 'limits and continuity' seemed to not have been helpful for many participants). Though the learning modules provided online had not been used very frequently, the satisfaction with these modules was higher.

Being asked what they would like to be changed, many students voted for a larger number of exercises and examples worked out in detail, plus more explanations on scientific notations and formulae.

## 4. Conclusion

The study preparation introduced in this article is a developing project that will be adapted and optimised based on the findings from monitoring and evaluation. Most of the students appreciated being offered a chance to self-assess and prepare for the courses of study. One objective of the project, raising awareness of the importance of basic mathematical skills, has been reached and the majority of prospective students were motivated to take part in the self-e-assessment provided.

It must be stated though that not all participants could benefit from the learning platform to the same extent. The results so far hint to the conclusion that self-study material can be used successfully mainly by students that already have acquired a certain body of knowledge that can be reactivated by engaging in the matter. To close bigger gaps or even build up new knowledge by way of self-study seems to be rather challenging for most students. Especially in categories where students lacked basic knowledge, like trigonometry or vectors, only slight improvements could be achieved. Particularly students with secondary degrees other than 'Abitur' could in average not benefit from the program at all.

With the overall sample being quite diverging, a group of 148 students that claimed having worked 7-10 learning modules could improve considerably between the two assessments. While many students stopped all activities after an initially high motivation, this group seemed to have found a way to motivate themselves. In the course of the project it should therefore be investigated in more detail when and why students tend to start or stop working with the given material. As the sample appears to be very heterogeneous not only in terms of knowledge but in terms of interest and ability to learn self-directed as well, different approaches might be needed to address these different types of learners.

With engineering students not particularly interested in mathematics, one approach might be the implementation of practical examples with relevance to engineering applications. On the other hand, referring to the learning interests some students indicated in the questionnaire, a major interest might be how to excel in examinations. In this case creating practical relevance would mean offering tools that help passing tests. This 'dilemma-driven' view on the use of mathematics has long been part of the 'practical relevance' discussion (cf. Lave, 1993; Holzkamp, 1993) and might be helpful when investigating aspects of learning interest and self-directed study.

Online e-assessment certainly is a helpful tool for students to learn about their knowledge and their deficiencies in mathematics and it may be used to initialize and structure the process of self-regulated learning. In addition assessments provide useful information for tertiary institutions about the changing mathematical backgrounds of their students that may be used to adjust curricula and contents of the courses to meet the need of the students and the requirements of the programs better.

**References**

Bennett, R.E. et al (2008) "Does it Matter if I Take My Mathematics Test on Computer? A Second Empirical Study of Mode Effects in NAEP", *Journal of Technology, Learning and Assessment* 6(9). [online] http://www.jtla.org.

Gershon, Richard C.; Bergstrom, Betty A. (2004) "Computerized adaptive testing". In Smith, Everett V.; Smith, Richard M. (Eds.) *Introduction to Rasch measurement: theory, models and applications*, Pennsylvania State University, JAM Press, pp. 601-629

Henn, Gudrun; Polaczek, Christa (2007) "Studienerfolg in den Ingenieurwissenschaften", *Das Hochschulwesen* 55 (5), S. 144–147. [online] http://www.fb6.fh-aachen.de/fileadmin/user_upload/Pdf/Presse/2007/0705xx_Studienerfolg.pdf

Holzkamp, Klaus (1993) *Lernen. Subjektwissenschaftliche Grundlegung*, Campus, Frankfurt am Main

Jordan, Sally (2007) "The mathematical misconceptions of adult distance-learning science students. Physics Innovations Centre for Excellence in Teaching and Learning", Open University [online] http://www.open.ac.uk/cetl-workspace/cetlcontent/documents/4738784f2e8a8.pdf

Jurecka, A (2008) "Introduction to the computer-based assessment of competencies". In Hartig et al (Eds) *Assessment of competencies in educational contexts,* Hogrefe, Göttingen, pp 193-213

Lave, Jean (1993) "Textaufgaben im Mathematikunterricht: Mikrokosmos der Widersprüche zwischen schulischem Lernen und außerschulischer Lebenspraxis", *Forum Kritische Psychologie* 31, pp 5-28

Lave, Jean (1993) "Word problems: a microcosm of theories of learning". In Light and Butterworth (eds) *Context and Cognition: Ways of Learning and Knowing*. Lawrence Erlbaum Associates. Hillsdale, NJ, pp 74-92

Nicol, D. J., & Macfarlane-Dick, D. (2006) "Formative assessment and self-regulated learning: A model and seven principles of good feedback practice", *Studies in Higher Education*, 31(2), [online] http://tltt.strath.ac.uk/REAP/public/Resources/DN_SHE_Final.pdf

A.14 Derr, K.; Hübl, R. (2012). “Online preparatory courses in Mathematics: Self-study courses for prospective students in engineering” (Original title: Studienvorbereitung Mathematik Online: Ein Selbstlernangebot für Studienanfänger/-innen in technischen Studiengängen). In: M. Ludwig and M. Kleine (eds.): Beiträge zum Mathematikunterricht, Münster: WTM, pp. 189–192.

DOI: http://dx.doi.org/10.17877/DE290R-8000

https://eldorado.tu-dortmund.de/bitstream/2003/32337/1/041.pdf

Katja DERR, Reinhold HÜBL, Mannheim

# Studienvorbereitung Mathematik Online: Ein Selbstlernangebot für Studienanfänger/-innen in technischen Studiengängen

## Ausgangslage

An der Fakultät Technik der DHBW Mannheim wurde im Wintersemester 2010 mit dem Aufbau einer Online-Plattform zur Studienvorbereitung Mathematik begonnen. Der Fokus liegt auf dem mathematischen Basiswissen, das für die Durchführung eines technischen Studiengangs vorausgesetzt wird. Tests zeigen, dass nicht alle Studienanfänger/-innen diese Grundlagenkenntnisse mitbringen, und dass bestehende erhebliche Defizite parallel zu den Anforderungen eines Studiums nur noch schwer abzubauen sind. Die Mathematik, für angehende Ingenieure nicht eigentliches Studieninteresse, kann so zu einem entscheidenden Faktor für Studienerfolg werden. Eine frühzeitige Sensibilisierung der Studienanfänger/-innen für die Bedeutung dieses Fachs ist darum zentraler Aspekt des Selbstlernangebots.

Das Konzept umfasst einen Online-Eingangstest, der idealerweise mehrere Monate vor Studienbeginn durchgeführt wird. Die Testergebnisse werden zusammen mit darauf basierenden Lernempfehlungen sowie Hinweisen auf entsprechende Lernmodule verschickt. Insgesamt werden zehn Lernmodule zur Grundlagenmathematik angeboten, die in Papierform oder alternativ als interaktive Lerneinheiten durchgearbeitet werden können (bislang werden drei von zehn Lernmodulen in der interaktiven Version angeboten, die Umstellung aller Lernmodule wird sukzessive erfolgen). Zu Studienbeginn wird ein zweiter (Kontroll-)Test durchgeführt, um zu ermitteln, welche Studierenden ein studienbegleitendes Tutorium besuchen sollten.

Die Testergebnisse sowie die Nutzung der Lernplattform werden in einer Studie unter Berücksichtigung folgender Fragestellungen untersucht:

1. Lassen sich über alle Teilnehmer/innen hinweg bzw. in bestimmten Teilnehmergruppen Defizite in bestimmten mathematischen Gebieten feststellen, die dann dementsprechend stärker in den Lernmaterialien berücksichtigt werden sollten?

2. Lassen sich zwischen den Testergebnissen und den statistischen Angaben der Teilnehmer/-innen Beziehungen herstellen, z.B. in Hinblick auf Schulform, Mathematik-Schulnote oder Bundesland?

3. Können die Nutzer/-innen des Selbstlernangebots ihr Testergebnis im Kontrolltest verbessern?

4. Gibt es Personengruppen, die von dem Selbstlernangebot stärker / weniger stark / gar nicht profitieren? Welche Faktoren sind förderlich bzw. hinderlich?

## 1. Ergebnisse in den mathematischen Gebieten

Die Testergebnisse im Eingangstest stimmen in weiten Teilen mit ähnlichen Untersuchungen überein, wie z.B. den an der Fachhochschule Aachen durchgeführten Eingangstests (vgl. Henn, Polaczek, 2007), und bestätigten die eigenen Ergebnisse des Vorjahres. So wurden in der Kategorie ‚Arithmetik und Elementares Rechnen' Aufgaben zur Prozentrechnung von einem Großteil der Teilnehmer richtig gelöst, während komplexere Termumformungen nur selten korrekt durchgeführt wurden.

Recht gute Ergebnisse ergaben sich für den Bereich der linearen und quadratischen ‚Gleichungen' (76,6% richtige Antworten), auch in den Kategorien ‚Funktionen' und ‚Potenzen, Wurzeln, Logarithmen' lagen die Werte über 60%.

In den Kategorien ‚Geometrie' und ‚Trigonometrie' waren die Ergebnisse weniger einheitlich: Während etwa Grundkenntnisse in der Dreiecksgeometrie bei einem Großteil der angehenden Studierenden vorhanden sind, wurden Aufgaben zu trigonometrischen Funktionen von vielen Testteilnehmern nicht gelöst. So ergaben sich für diese Kategorien Durchschnittsergebnisse von ca. 45%. Neben der Trigonometrie kann offenbar auch das Themengebiet Vektorrechnung nicht als Grundlagenwissen vorausgesetzt werden: Hier wurden nur 36,4% erreicht.

## 2. Statistische Einflussfaktoren

Um unterschiedliche Gruppen und ihre Entwicklung zwischen Eingangs- und Kontrolltest besser vergleichen zu können, wurden beide Tests so normiert, dass die Mittelwerte jeweils bei 100 Punkten lagen. Bei den meisten der untersuchten statistischen Einflussfaktoren wie Geschlecht, Bundesland, Studiengang, G8 oder G9, konnte kein statistisch signifikanter Zusammenhang mit den Testergebnissen festgestellt werden. Relativ deutlich war der Zusammenhang mit der Mathematiknote: Teilnehmer, die angegeben hatten in Mathematik überwiegend sehr gute Noten zu haben, erreichten höhere Testergebnisse und konnten sich zwischen Eingangs- und Kontrolltest am deutlichsten verbessern (Eingangstest: 113,75; Kontrolltest: 119,91 Punkte). Teilnehmer mit guten bzw. befriedigenden Mathematiknoten haben in beiden Tests etwas schlechter abgeschnitten und die Verbesserung von Eingangstest zu Kontrolltest war weniger stark.

Statistisch signifikant war auch der Zusammenhang zwischen Testergebnis und Art der Hochschulzugangsberechtigung: Im Vergleich zu den Teilnehmern mit allgemeiner Hochschulreife (n=457), die im Eingangstest 101,94 und im Kontrolltest 106,92 Punkte erreichten, erzielte die Gruppe der Teilnehmer mit Fachhochschulreife (n=46) im Eingangstest einen Durchschnittswert von 81,80 und im Kontrolltest 78,85. Auch wenn diese Gruppe zahlenmäßig sehr klein ist, kann von einem stabilen Zusammenhang ausgegangen werden, da in 2010 ähnliche Ergebnisse erzielt wurden.

### 3. Effekt des Selbstlernangebots

524 der 724 Studienanfänger/-innen nahmen am Online-Eingangstest teil, nach Durchführung bearbeiteten nach eigener Auskunft fast 90% der Eingangstest-Teilnehmer ein oder mehrere der insgesamt zehn verfügbaren Lernmodule. Am Kontrolltest nahmen dann 718 Teilnehmer teil (wobei 90 Teilnehmer weder den Eingangstest durchgeführt noch Lernmodule bearbeitet haben). Die 506 Teilnehmer, die beide Tests durchgeführt haben, verbesserten sich von 99,96 Punkten im Eingangstest auf durchschnittlich 104,18 Punkte im Kontrolltest. Im Vergleich dazu erreichten die Teilnehmer, die nur den Kontrolltest durchgeführt haben und auch keine Lernmodule bearbeiteten, mit 88,99 einen deutlich geringeren Mittelwert.

Studienanfänger/-innen, die mindestens ein Lernmodul bearbeitet haben, erzielten im Eingangstest durchschnittlich 99,87, im Kontrolltest 104,31 Punkte. Testteilnehmer/-innen, die keine Lernmodule bearbeitet haben (n=37) verbesserten sich weniger stark von 102,36 im Eingangstest auf 103,25 Punkte im Kontrolltest, die Unterschiede sind allerdings statistisch nicht signifikant.

Ein eindeutiger Zusammenhang zwischen Lernmodul-Bearbeitung und Kontrolltestergebnis lässt sich also trotz der durchschnittlichen Ergebnis-Verbesserung nicht für alle Teilnehmergruppen und auch nicht für alle Lernmodule gleichermaßen nachweisen.

### 4. Adressatengruppen

Die stärkste Verbesserung zwischen Eingangstest und Kontrolltest ist bei Teilnehmern zu beobachten, die ein weniger gutes Eingangstestergebnis hatten und dementsprechend viele Lernempfehlungen erhalten haben. In dieser Gruppe haben Studienanfänger/-innen mit guten Mathematik-Noten (n=141) am meisten von der Nutzung der Lernmodule profitiert und sich stärker verbessert als die Teilnehmer dieser Gruppe, die keine Lernmodule bearbeitet haben. Dies gilt besonders für die mathematischen Kategorien ‚Arithmetik', ‚Logik und Kombinatorik', ‚Potenzen, Wurzeln Logarithmen' sowie ‚Funktionen'. Die Ergebnisse weisen darauf hin, dass das Angebot in der jetzigen Form vor allem Studienanfänger/-innen mit bestehendem Grundwissen erreicht, die es nutzen um vorhandene Kenntnisse aufzufrischen. Das Schließen großer Wissenslücken bzw. die Erarbeitung komplett neuer Lerninhalte kann hingegen nicht erwartet werden. So konnten in Kategorien, in denen die Studienanfänger/-innen laut Selbstauskunft wenig bis keine Vorkenntnisse mitbringen, wie z.B. Trigonometrie oder Vektorrechnung, nur geringe Verbesserungen erreicht werden. Insbesondere gelang es nicht, den Rückstand der Teilnehmer mit Fachhochschulreife bzw. beruflicher Qualifizierung zu verringern, auch ein zusätzlich für diese Gruppe durchgeführtes Präsenzseminar wirkte sich kaum auf die Testergebnisse aus.

### 5. Fazit

Das Selbstlernangebot wurde von der Mehrzahl der angehenden Studierenden als Hilfe zur Studienvorbereitung begrüßt und genutzt. Eine mit 503 Teilnehmern durchgeführte Evaluation ergab, dass sich viele Teilnehmer allerdings mehr Übungsaufgaben wünschen, sowie mehr Erklärungen zu Notationen und Formeln.

Im weiteren Projektverlauf soll genauer untersucht werden, welche Gründe bei den angehenden Studierenden bestehen, Lernhandlungen aufzunehmen, fortzuführen bzw. abzubrechen. Um die anfänglich recht hohe Motivation aufrecht zu erhalten, sollen verstärkt anwendungsbezogene Beispiele zum Einsatz kommen, die in Kooperation mit den Partnerunternehmen der DHBW Mannheim entwickelt werden. Über mathematische Anwendungen aus der täglichen Ingenieurspraxis soll die Motivation zur Beschäftigung mit mathematischen Fragestellungen erhöht werden und die Bedeutung der Mathematik für das angestrebte Studium unterstrichen werden.

Hinweis: Bei Interesse kann ein Zugang zum Portal eingerichtet werden, es genügt eine formlose E-Mail an: zemath@dhbw-mannheim.de

### Literatur


Henn, Gudrun; Polaczek, Christa (2007). Studienerfolg in den Ingenieurwissenschaften. Das Hochschulwesen 55 (5), S. 144–147. http://www.fb6.fh-aachen.de/fileadmin/user_upload/Pdf/Presse/2007/0705xx_Studienerfolg.pdf [12.11.11]

Jordan, Sally (2007). The mathematical misconceptions of adult distance-learning science students. Physics Innovations Centre for Excellence in Teaching and Learning, Open University. http://www.open.ac.uk/cetl-workspace/cetlcontent/documents/ 4738784f2e8a8.pdf [04.09.2010]

Opfermann, M., & Wirth, J. (2008). Self-regulated learning with multimedia. International Journal of Psychology, 43(2-3), S. 39

# B Descriptive data

## B.1 Pre-and main study (2011-2016)

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| No pre-course participation (post-test only) | 209 | 186 | 119 | 105 | 156 | 171 |
| Pre-course participation (pre- and post-test) | 506 | 642 | 597 | 603 | 551 | 596 |
| Total | 715 | 828 | 716 | 708 | 707 | 767 |

*Sample 2011-2016*

**Gender**

Source: university's administration

The percentage of female students was 13.7 on average. There was a slight increase over the six years from 11% in 2011 to 16% in 2016. Statistically this increase was not relevant (Chi-square test was not significant, $p$ = .481).

| | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | | 2016 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % | n | % |
| male | 639 | 89.4 | 719 | 86.8 | 619 | 86.5 | 615 | 86.9 | 598 | 84.6 | 641 | 83.6 |
| female | 76 | 10.6 | 109 | 13.2 | 97 | 13.5 | 93 | 13.1 | 109 | 15.4 | 126 | 16.4 |
| total | 715 | | 828 | | 716 | | 708 | | 707 | | 767 | |

*Table 1 Male / female engineering students 2011 to 2016*

**Age / gap between secondary and tertiary education**

Source: university's administration

Nearly 75% of the first-year students graduated from secondary school in the year of university enrolment and another 15% took up the degree programme one year later. Thus the number of students with gaps between school and university of two years, or more, was between 12 and 15%.

The abridgement of secondary school duration from nine to eight years led to a doubling of graduates in Baden-Wuerttemberg in 2012. In that year the number of students who had graduated in the same year was significantly higher, with 78% of the cohort. Otherwise, no trend or significant differences between cohorts could be observed.

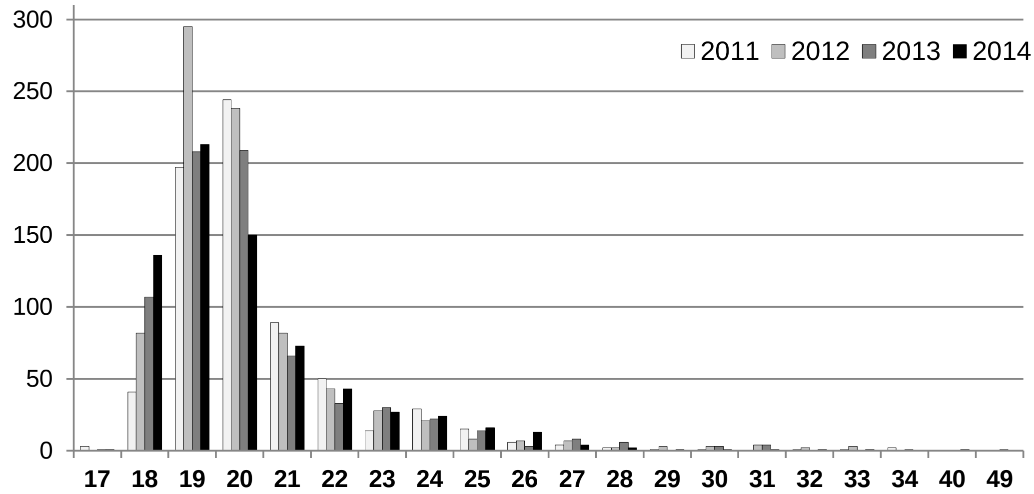
Chi-Square test of independence: $\chi^2$ ($n$ = 2836, 9) = 42.369, $p$ < .001; φ = .122

| | 2011 | | 2012 | | 2013 | | 2014 | | Ø | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % |
| same year | 466 | 66.7 | 640 | 78.1 | 513 | 73.2 | 428 | 69.4 | 2047 | 72.2 |
| distance = one year | 146 | 20.9 | 84 | 10.3 | 92 | 13.1 | 99 | 16.0 | 421 | 14.8 |
| distance = two years | 21 | 3.0 | 28 | 3.4 | 28 | 4.0 | 27 | 4.4 | 104 | 3.7 |
| distance >= three years | 66 | 9.4 | 67 | 8.2 | 68 | 9.7 | 63 | 10.2 | 264 | 9.3 |
| total | 699 | 100 | 819 | 100 | 701 | 100 | 617 | 100 | 2836 | 100 |

*Distance between secondary school graduation and university (missing: 2011 n=16; 2012 n=9; 2013 n= 17; 2014 n=91)*

The average age of a first year students was 20.4 years in 2011, and 20.2 years in 2014. The majority of first-year students were 19 or 20 years old, with an increase of younger students from 2011 to 2014, due to the successive abridgement of secondary school duration from nine to eight years in most federal states in Germany. Thus in 2011 the twenty-year-olds were the largest group with 35% while in 2014 they were outnumbered by the group of nineteen-year-olds (30% vs. 21%). The percentage of eighteen-year-olds increased from 6% in 2011 to 19% in 2014 (see table and bar chart).

| | n | mean | median | variance | stand. dev. | min. | max. |
|---|---|---|---|---|---|---|---|
| 2011 | 700 | 20.4 | 20 | 4.222 | 2.055 | 17 | 34 |
| 2012 | 828 | 20.2 | 20 | 5.039 | 2.245 | 18 | 33 |
| 2013 | 716 | 20.3 | 20 | 6.248 | 2.500 | 17 | 49 |
| 2014 | 708 | 20.2 | 20 | 5.407 | 2.325 | 17 | 40 |
| total | 2952 | 20.3 | 20 | 5.229 | 2.287 | 17 | 49 |




*Age distribution first year students 2011-2014*

**Federal state**

Source: statistical questionnaire

The biggest group of students (25%) stem from Baden-Wuerttemberg, the second biggest group is Rheinland-Pfalz area with 21 per cent, and Hessen with 19.

| | 2011 | | 2012 | | 2013 | | 2014 | | Ø | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | % | n | % | n | % |
| Baden-Wuerttemberg | 163 | 23.3 | 235 | 28.7 | 166 | 23.9 | 152 | 24.6 | 716 | 25.3 |
| Rheinland-Pfalz | 135 | 19.3 | 199 | 24.3 | 148 | 21.3 | 125 | 20.2 | 607 | 21.4 |
| Hessen | 126 | 18.0 | 126 | 15.4 | 163 | 23.4 | 130 | 21.0 | 545 | 19.2 |
| Nordrhein-Westfalen | 60 | 8.6 | 79 | 9.6 | 101 | 14.5 | 65 | 10.5 | 305 | 10.8 |
| Bayern | 86 | 12.3 | 53 | 6.5 | 56 | 8.0 | 54 | 8.7 | 249 | 8.8 |
| Other German states | 127 | 18.2 | 126 | 15.4 | 62 | 8.9 | 90 | 14.6 | 405 | 14.3 |
| Foreign | 2 | 0.3 | 2 | 0.2 | | 0.0 | 2 | 0.3 | 6 | 0.2 |
| **total** | **699** | | **820** | | **696** | | **618** | | 2833 | |

*Federal state / origin first year students 2011-2014*

**Secondary school education: type of school**

Source: university’s administration

The majority of first-year students in all four years had graduated from secondary school with a general *Abitur*. More than 70% of each cohort could be assigned to this group. The second biggest group were students from schools with a focus on technology or economics (*Berufliches Gymnasium*) and the third relevant group were students who had attended a vocational school (*Fachhochschulreife*). Two rather small groups were students who already had worked in a related profession (*Beruflich qualifiziert*), or had achieved their certificate of access to higher education part-time, at evening schools, or in a foreign country (“other”).

| | 2011 | | 2012 | | 2013 | | 2014 | | Ø | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | n | % | n | % | n |
| *Abitur* | 519 | 72.6 | 582 | 70.3 | 528 | 73.7 | 500 | 70.6 | 2129 | 71.8 |
| *Berufliches Gymnasium* | 112 | 15.7 | 134 | 16.2 | 81 | 11.3 | 95 | 13.4 | 422 | 14.2 |
| *Fachhochschulreife* | 73 | 10.2 | 100 | 12.1 | 83 | 11.6 | 88 | 12.4 | 344 | 11.6 |
| *Beruflich qualifiziert* | 6 | 0.8 | 9 | 1.1 | 7 | 1.0 | 7 | 1.0 | 29 | 1.0 |
| other | 5 | 0.7 | 3 | 0.4 | 17 | 2.4 | 18 | 2.5 | 43 | 1.4 |
| total | 715 | | 828 | | 716 | | 708 | | 2967 | |

*Type of secondary school graduation (Abitur: allows progression to tertiary education; Berufliches Gymnasium: Abitur, but with a focus on technical or economic subjects; Fachhochschulreife: allows progression to universities of applied sciences; Beruflich qualifiziert: qualified via professional experience)*

**Secondary school education: final grades**

The distributions of final grades were positively skewed in all four years, with "good" grades (original scores: around 2; reverse scores: around 3) being most frequent.

| | n | mean | median | variance | stand. dev. | stand. err. | min. | max. |
|---|---|---|---|---|---|---|---|---|
| 2011 | 714 | 2.18 | 2.1 | 0.27 | 0.52 | 0.02 | 1.0 | 3.7 |
| 2012 | 825 | 2.18 | 2.2 | 0.30 | 0.55 | 0.02 | 1.0 | 3.8 |
| 2013 | 714 | 2.17 | 2.2 | 0.30 | 0.55 | 0.02 | 1.0 | 3.7 |
| 2014 | 703 | 2.20 | 2.2 | 0.29 | 0.53 | 0.02 | 1.0 | 3.7 |

*Final school grades first year students 2011-2014 (definition of grades: 1 (0.7 to 1.4) = "very good" ; 2 (1.5 to 2.4) = "good"; 3 (2.5 to 3.4) = "fair"; 4 (3.5 to 4.4) = "pass"); (missing: 2011 n=4; 2012 n=26 ; 2013 n= 11; 2014 n=5)*

| German school grades | | | approx. converted to UK system |
|---|---|---|---|
| sehr gut | very good | 1.0 to 1.5 | A*-A |
| gut | good | 1.6 to 2.5 | A-B |
| befriedigend | satisfactory | 2.6 to 3.5 | B-C |
| ausreichend | sufficient | 3.6 to 4.0 | C-D |
| nicht ausreichend / nicht bestanden | insufficient / failed | 4.1 to 5.0 | E-F |
| mangelhaft / nicht bestanden | inadequate / failed | 5.1 to 6.0 | F-G |

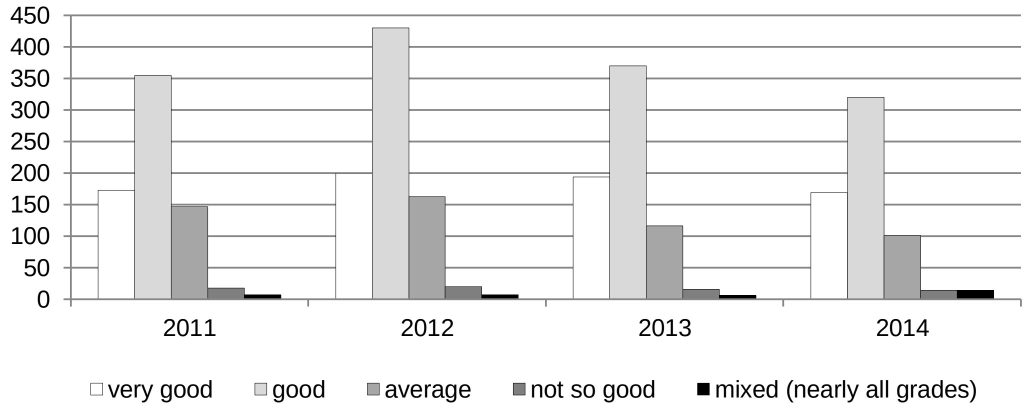
*Grading systems Germany / UK*

**Secondary school education: mathematics grades**

Source: statistical questionnaire

In the questionnaire students were asked which mathematics grades they mostly had during the last years at secondary school. As final grades, these data were not normally distributed. Fifty per cent of the students reported “good” grades in mathematics, and another 25% had been “very good”. The distribution did not change significantly during the four years of observation.

| | 2011 | | 2012 | | 2013 | | 2014 | | total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | % | n | % | n | n | % | n | % | n |
| very good | 173 | 24.7 | 200 | 24.4 | 194 | 27.6 | 169 | 27.3 | 736 | 25.9 |
| good | 355 | 50.7 | 430 | 52.4 | 370 | 52.7 | 320 | 51.8 | 1475 | 51.9 |
| average | 147 | 21.0 | 163 | 19.9 | 116 | 16.5 | 101 | 16.3 | 527 | 18.6 |
| not so good | 18 | 2.6 | 20 | 2.4 | 16 | 2.3 | 14 | 2.3 | 68 | 2.4 |
| mixed (nearly all grades) | 7 | 1.0 | 7 | 0.9 | 6 | 0.9 | 14 | 2.3 | 34 | 1.2 |
| total | 700 | | 820 | | 702 | | 618 | | 2840 | |




*First year students’ self-reported mathematics grades at secondary school (missing: 2011 n=15; 2012 n=8 ; 2013 n= 14; 2014 n=90)*

**Degree programme**

Mechanical engineering is the largest course of study at DHBW Mannheim (32 per cent of first-year engineering students), followed by Mechatronics (20%), Electrical engineering (19%), Computer science (16%), and Industrial engineering (13%). These distributions remained quite stable throughout the four years.

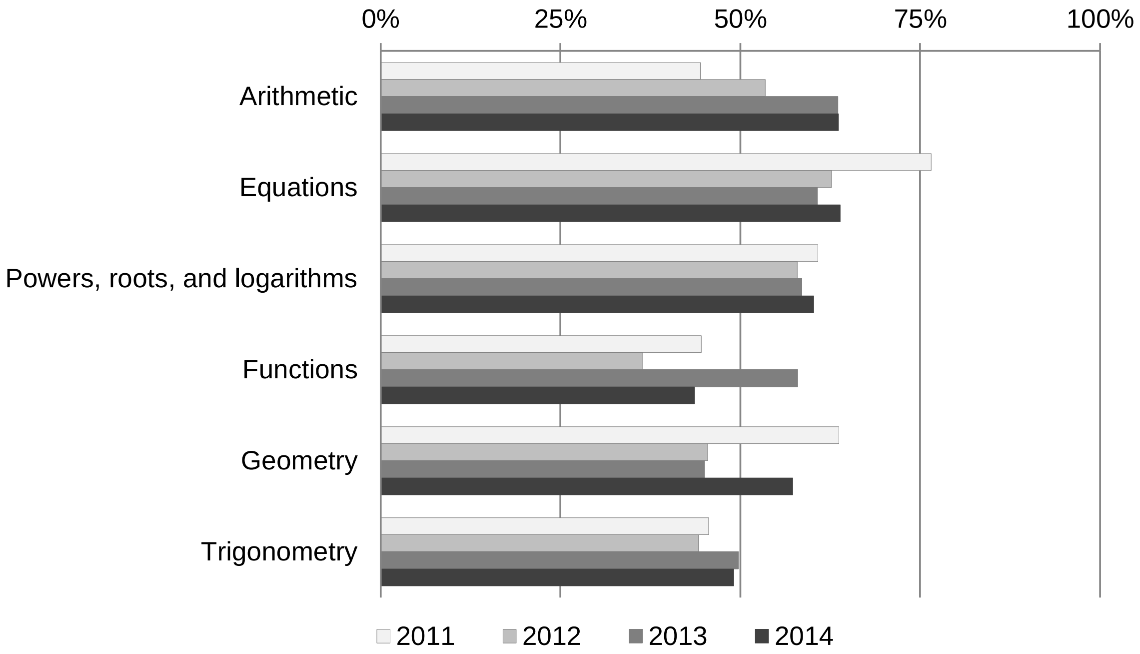
| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Computer science | 116 | 126 | 122 | 117 | 120 | 120 |
| Industrial engineering | 85 | 102 | 101 | 101 | 109 | 103 |
| Mechatronics | 152 | 169 | 141 | 120 | 125 | 139 |
| Electrical engineering | 132 | 178 | 128 | 135 | 140 | 160 |
| Mechanical engineering | 230 | 253 | 224 | 235 | 213 | 245 |
| Total | 715 | 828 | 716 | 708 | 707 | 767 |

*First year students per degree programme 2011 to 2016*

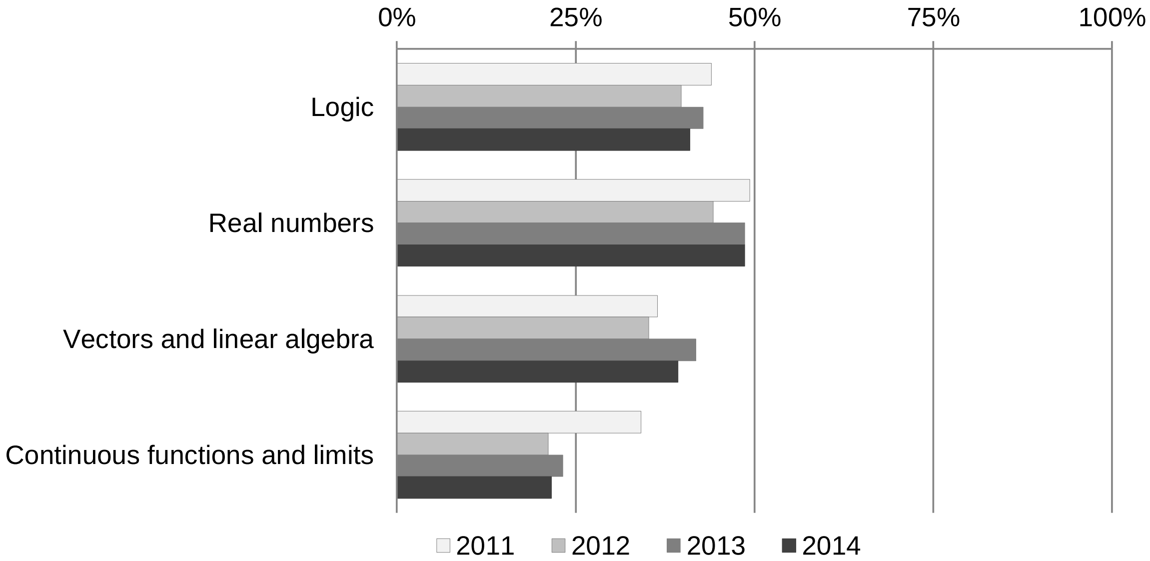
Regarding the interaction with other personal variables, it could be observed that the percentage of female students was higher in Industrial engineering than in any other course, with a rate of up to 30% in 2013 (versus the overall percentage of female students of 13). There also was an interaction between degree programme and secondary school grades, with slightly better grades for Industrial engineering (2.09 vs. 2.18 on average). t-tests revealed significant differences between students of this degree programme and Mechanical engineering; per cohort this effect was only significant in 2014.

Computer science students more often had very good school grades in mathematics than the average (32% vs. 26%) whereas Mechatronics students had the smallest percentage of „very good“ mathematics grades. Per cohort, this effect was not significant, probably due to smaller sample sizes (in 2011, for example, Electrical engineering students had the highest percentage of “very good grades” in mathematics).

**Pre-test results per mathematical field**




*Pre-test results per mathematical field (2011-2014): basic curriculum*




*Pre-test results per mathematical field (2011-2014): extended curriculum*

## Learning module participation

| | 2013 | | 2014 | |
|---|---|---|---|---|
| | n | % | n | % |
| total (participants both tests + evaluation questionnaire) | 577 | | 205 | |
| missing (participants both tests but evaluation not answered) | 20 | | 398 | |
| participants who used at least one learning module | 460 | 79.7 | 178 | 86.8 |

**Which of the ten learning modules did you work through?**

| | | 2013 n | 2013 % | 2014 n | 2014 % |
|---|---|---|---|---|---|
| basic curriculum | | n | % | n | % |
| 1 | Arithmetic | 286 | 49.6 | 143 | 69.8 |
| 2 | Equations | 212 | 36.7 | 133 | 64.9 |
| 3 | Squares, roots, logarithms | 188 | 32.6 | 118 | 57.6 |
| 4 | Functions | 226 | 39.2 | 119 | 58.0 |
| 5 | Geometry | 201 | 34.8 | 124 | 60.5 |
| 6 | Trigonometry | 179 | 31.0 | 117 | 57.1 |
| extended curriculum | | | | | |
| 7 | Logic | 122 | 21.1 | 45 | 22.0 |
| 8 | Real numbers | 102 | 17.7 | 43 | 21.0 |
| 9 | Vectors and linear algebra | 151 | 26.2 | 43 | 21.0 |
| 10 | Continuous functions and limits | 98 | 17.0 | 40 | 19.5 |
| used but forgot the name / topic | | 159 | 27.6 | 27 | 13.2 |

*Self reported use of learning modules 2013 and 2014 (evaluation questionnaire, item10, see Appendix D.4)*

## B.2 Main study (2014-2016): Course types

| | 2014 | 2015 | 2016 |
|---|---|---|---|
| self-study (participation both tests) | 386 | 392 | 408 |
| face-to-face course | 91 | 70 | 81 |
| e-tutoring course (with certificate) | 85 | 51 | 77 |
| face-to-face plus e-tutoring (with certificate) | 28 | 38 | 15 |
| pre-course participation total | 603 | 551 | 596 |
| post-test only | 105 | 156 | 171 |
| total | 708 | 707 | 767 |

*participants per course type (2014-2016)*

**Gender**

There were no significant differences between male and femals students per course type. ($\chi^2$ test (4, $n$ = 708) = 4.489, $p$ = .344).

| | | m | f | total |
|---|---|---|---|---|
| self-study (participation both tests) | n | 346 | 53 | 399 |
| | % | 86.7 | 13.3 | 100 |
| face-to-face course | n | 75 | 16 | 91 |
| | % | 82.4 | 17.6 | 100 |
| e-tutoring course | n | 73 | 12 | 85 |
| | % | 85.9 | 14.1 | 100 |
| face-to-face plus e-tutoring | n | 24 | 4 | 28 |
| | % | 85.7 | 14.3 | 100 |
| post-test only | n | 97 | 8 | 105 |
| | % | 92.4 | 7.6 | 100 |
| total | n | 615 | 93 | 708 |
| | % | 86.9 | 13,1 | 100 |

*male/female students per course type (2014)*

**Age / gap between secondary and tertiary education**

The mean age of first-year students was 20.2, and in the face-to-face group as well as in the post-test only group the average age was higher (20.7). This effect was caused by the fact that FHR students, who were higher represented in these groups, as well, also tend to be elder than AHR students (who were higher represented in self-study and e-tutoring).

| | n | mean | median | variance | stand. dev. | stand. err. | min. | max. |
|---|---|---|---|---|---|---|---|---|
| self-study (participation both tests) | 399 | 19.8 | 19 | 3.845 | 1.961 | 0.098 | 17 | 31 |
| face-to-face course | 91 | 20.7 | 20 | 4.619 | 2.149 | 0.225 | 18 | 27 |
| e-tutoring course | 85 | 20.1 | 19 | 4.551 | 2.133 | 0.231 | 18 | 28 |
| face-to-face plus e-tutoring | 28 | 21.5 | 21 | 12.259 | 3.501 | 0.662 | 18 | 33 |
| post-test only | 105 | 20.7 | 20 | 9.766 | 3.125 | 0.305 | 18 | 40 |
| total | 708 | 20.2 | 20 | 5.407 | 2.325 | 0.087 | 17 | 40 |

*Students' average age per course type (2014)*

The gap between school and university showed similar distributions. The higher representation of students with more than one year gap in face-to-face course is quite obvious, but the effect is weak and it should be taken into account that the data in this rather small group are very heterogeneous. ($\chi^2$ test (12, $n$ = 617) = 25.932, $p < .05$, φ = .205, Cramer-V = .118)

| | | same year | one year gap | two year gap | >= three years | total |
|---|---|---|---|---|---|---|
| self-study (participation both tests) | n | 284 | 62 | 18 | 31 | 395 |
| | % | 71.9 | 15.7 | 4.6 | 7.8 | 100 |
| face-to-face course | n | 56 | 14 | 3 | 16 | 89 |
| | % | 62.9 | 15.7 | 3.4 | 18.0 | 100 |
| e-tutoring course | n | 64 | 14 | 1 | 6 | 85 |
| | % | 75.3 | 16.5 | 1.2 | 7.1 | 100 |
| face-to-face plus e-tutoring | n | 14 | 6 | 2 | 6 | 28 |
| | % | 50.0 | 21.4 | 7.1 | 21.4 | 100 |
| *post-test only (85 missing)* | *n* | *10* | *3* | *3* | *4* | *20* |
| | *%* | *50.0* | *15.0* | *15.0* | *20.0* | *100* |
| total | n | 428 | 99 | 27 | 63 | 617 |
| | % | 69.4 | 16.0 | 4.4 | 10.2 | 100 |

*Gap between secondary school and university per course type (2014)*

**Federal state**

Students from the federal state of Baden-Wuerttemberg were more likely to participate in the face-to-face course, followed by students from Rheinland-Pfalz and Hessen (Chi-square test (16, $n$ = 526) = 42.835, $p$ < .001, phi = .285, Cramer-V = .143).

| | | Baden-Wuerttem-berg | Bayern | Hessen | NRW | Rheinland-Pfalz | total |
|---|---|---|---|---|---|---|---|
| self-study (participation both tests) | n | 79 | 50 | 83 | 44 | 79 | 335 |
| | % | 23.6 | 14.9 | 24.8 | 13.1 | 23.6 | 100 |
| face-to-face course | n | 33 | 2 | 18 | 8 | 23 | 84 |
| | % | 39.3 | 2.4 | 21.4 | 9.5 | 27.4 | 100 |
| e-tutoring course | n | 21 | 0 | 21 | 11 | 15 | 68 |
| | % | 30.9 | 0.0 | 30.9 | 16.2 | 22.1 | 100 |
| face-to-face plus e-tutoring | n | 9 | 1 | 6 | 1 | 7 | 24 |
| | % | 37.5 | 4.2 | 25.0 | 4.2 | 29.2 | 100 |
| *post-test only (85 missing)* | *n* | *10* | *1* | *2* | *1* | *1* | *15* |
| | *%* | *66.7* | *6.7* | *13.3* | *6.7* | *6.7* | *100* |
| total | n | 152 | 54 | 130 | 65 | 125 | 526 |
| | % | 28.9 | 10.3 | 24.7 | 12.4 | 23.8 | 100 |

*Federal state (five biggest states) per course type (2014)*

**Secondary school education: type of school**

In the face-to-face version of the pre-course the rate of students from a secondary school leading to FHR is higher than in the whole sample (26% vs. 13%); self-study group (7%); e-tutoring: 15%. ($\chi^2$ test (8, $n$ = 683) = 31.540, $p$ < .001, $\varphi$ = .215, Cramer-V = .152)

| | | AHR: Gym | AHR: Bgym | FHR | total |
|---|---|---|---|---|---|
| self-study (participation both tests) | n | 303 | 58 | 29 | 390 |
| | % | 77.7 | 14.9 | 7.4 | 100 |
| face-to-face course | n | 51 | 14 | 23 | 88 |
| | % | 58.0 | 15.9 | 26.1 | 100 |
| e-tutoring course | n | 60 | 8 | 12 | 80 |
| | % | 75.0 | 10.0 | 15.0 | 100 |
| face-to-face plus e-tutoring | n | 19 | 3 | 4 | 26 |
| | % | 73.1 | 11.5 | 15.4 | 100 |
| post-test only | n | 67 | 12 | 20 | 99 |
| | % | 67.7 | 12.1 | 20.2 | 100 |
| total | n | 500 | 95 | 88 | 683 |
| | % | 73.2 | 13.9 | 12.9 | 100 |

*Type of secondary school per course type (2014)*

**Secondary school education: final grades**

Face-to-face course participants' school grades were poorer than average, and also poorer than those of e-tutoring course participants. The pairwise comparisons in the ANOVA were significant (f2f vs. self-study: $p < .01$; f2f vs. e-tutoring: $p < .01$). The final school grades of students who did not participate in the pre-course were the poorest (mean score = 2.4) and significantly different from those of self-study ($p < .001$) and e-tutoring ($p < .001$) participants.

| | n | mean | median | variance | stand. dev. | stand. err. | min. | max. |
|---|---|---|---|---|---|---|---|---|
| self-study (participation both tests) | 399 | 2.1 | 2.1 | 0.251 | 0.501 | 0.025 | 1.0 | 3.7 |
| face-to-face course | 89 | 2.3 | 2.3 | 0.298 | 0.546 | 0.058 | 1.1 | 3.5 |
| e-tutoring course | 84 | 2.1 | 2.0 | 0.297 | 0.545 | 0.060 | 1.0 | 3.4 |
| face-to-face plus e-tutoring | 27 | 2.5 | 2.4 | 0.306 | 0.553 | 0.106 | 1.6 | 3.4 |
| post-test only | 104 | 2.4 | 2.4 | 0.289 | 0.538 | 0.053 | 1.2 | 3.5 |
| total | 703 | 2.2 | 2.2 | 0.285 | 0.534 | 0.020 | 1.0 | 3.7 |

*Secondary school grades per course type (2014) (definition of grades: 1 (0.7 to 1.4) = "very good" ; 2 (1.5 to 2.4) = "good"; 3 (2.5 to 3.4) = "fair"; 4 (3.5 to 4.4) = "pass"); (missing: 2011 n=4; 2012 n=26 ; 2013 n= 11; 2014 n=5)*

**Secondary school education: mathematics grades**

Note: for statistical analyses the groups “average” ($n$ = 101), “not so good”($n$ = 14), and “mixed (nearly all grades)” ($n$ = 14) were combined into one group: “average to poor grades” ($n$ = 129).

In the face-to-face version of the pre-course the rate of students with medium to poor mathematics grades was higher than in the whole sample (30% vs. 21%). Students with medium to poor grades were also more likely to not participate in the pre-course at all (25%), indicating that this group either enrolled too late, were not informed, or chose to not participate in the programme. ($\chi^2$ test (8, $n$ = 618) = 17.791, $p > .05$, $\varphi = .170$, Cramer-V = .120).

| | | average to poor | good | very good | total |
|---|---|---|---|---|---|
| self-study (participation both tests) | n | 69 | 211 | 115 | 395 |
| | % | 17.5 | 53.4 | 29.1 | 100 |
| face-to-face course | n | 27 | 43 | 20 | 90 |
| | % | 30.0 | 47.8 | 22.2 | 100 |
| e-tutoring course | n | 16 | 43 | 26 | 85 |
| | % | 18.8 | 50.6 | 30.6 | 100 |
| face-to-face plus e-tutoring | n | 12 | 13 | 3 | 28 |
| | % | 42.9 | 46.4 | 10.7 | 100 |
| post-test only | n | 5 | 10 | 5 | 20 |
| | % | 25.0 | 50.0 | 25.0 | 100 |
| total | n | 129 | 320 | 169 | 618 |
| | % | 20.9 | 51.8 | 27.3 | 100 |

*Self-reported mathematics grades per course type (2014)*

**Pre-test results**

Pre-test results of face-to-face and e-tutoring participants were poorer than those of the self-study students. With an average mean of 48 students in the e-tutoring course performed better than those who chose the face-to-face course (mean = 44). (ANOVA: $df1 = 3$, $df2 = 599$, $F = 9.005$, $p < .001$)

| | n | mean | median | variance | stand. dev. | stand. err. | min. | max. |
|---|---|---|---|---|---|---|---|---|
| self-study (participation both tests) | 399 | 51.97 | 52.94 | 276.043 | 16.615 | 0.832 | 7.06 | 92.94 |
| face-to-face course | 91 | 43.65 | 43.53 | 187.260 | 13.684 | 1.435 | 10.59 | 78.82 |
| e-tutoring course | 85 | 47.49 | 45.88 | 198.139 | 14.076 | 1.527 | 20.00 | 84.71 |
| face-to-face plus e-tutoring | 28 | 44.24 | 42.94 | 139.161 | 11.797 | 2.229 | 22.35 | 70.59 |
| total | 603 | 49.72 | 49.41 | 255.406 | 15.981 | 0.651 | 7.06 | 92.94 |

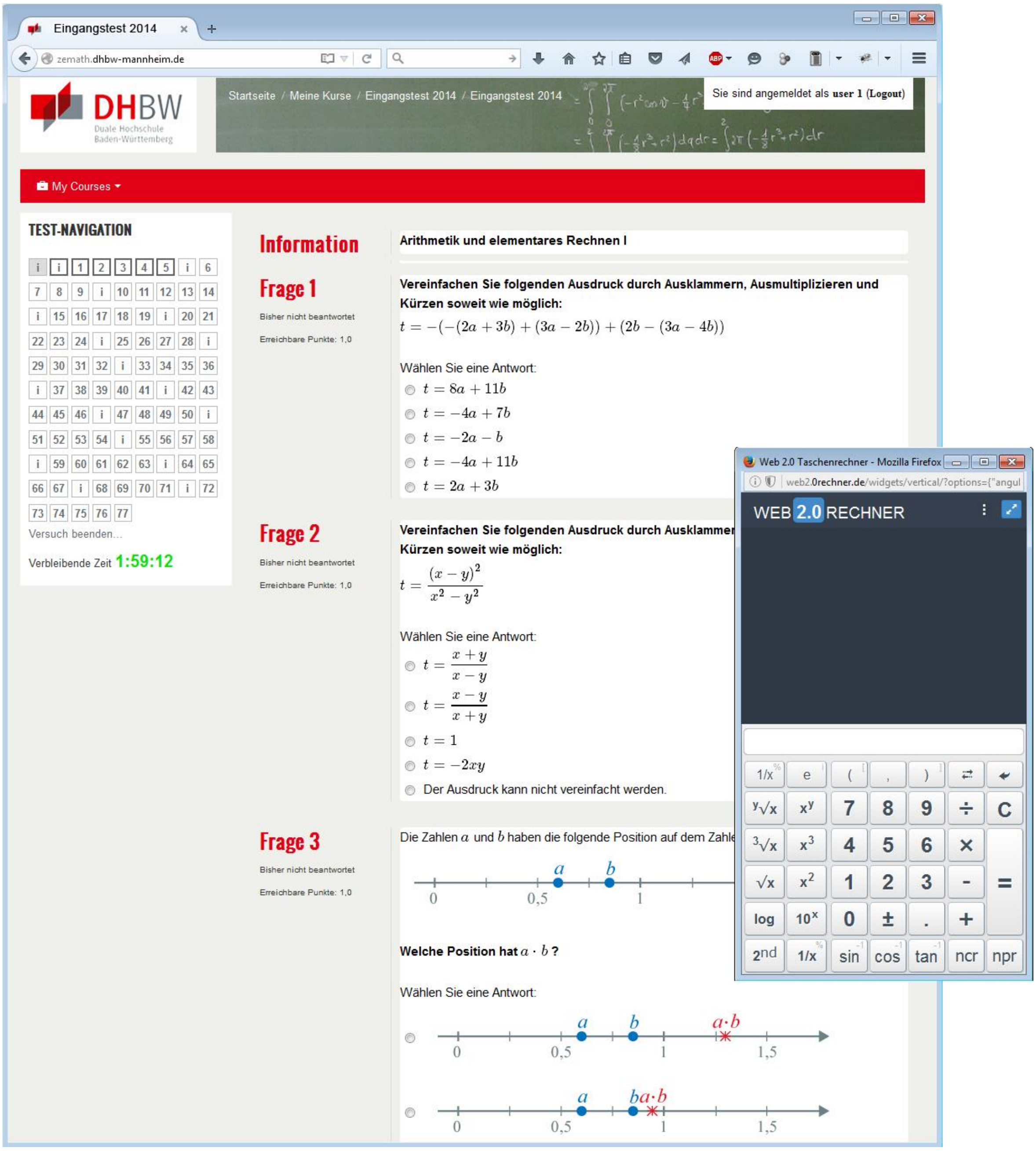
*Pre-test results per course type (2014)*

# C Quantitative tools: pre- and post-test

## C.1 Pre-test items

77 pre-test items, final version of 2014

*Note:* this is the printed / pdf version of the e-elearning quiz. For the original layout see screenshot below (diagnostic pre-test 2014, arithmetic, questions 1-3, pop-up calculator).



# 1 Arithmetik I

***Aufgabenname:*** *ari_ter_kla_101*

**Aufgabe 1.1.** Vereinfachen Sie den folgenden Ausdruck durch Ausklammern, Ausmultiplizieren und Kürzen soweit, wie möglich:

$$t = -(-(2a + 3b) + (3a - 2b)) + (2b - (3a - 4b))$$

- ☐ $t = 8a + 11b$
- ☐ $t = -4a + 11b$
- ☐ $t = 2a + 3b$
- ☐ $t = -4a + 7b$
- ☐ $t = -2a - b$

***Lösung:***

- ☑ $t = -4a + 11b$

***Aufgabenname:*** *ari_ter_bin_105*

**Aufgabe 1.2.** Vereinfachen Sie den folgenden Ausdruck durch Ausklammern, Ausmultiplizieren und Kürzen soweit, wie möglich:

$$t = \frac{(x - y)^2}{x^2 - y^2}$$

- ☐ $t = \frac{x + y}{x - y}$
- ☐ $t = \frac{x - y}{x + y}$
- ☐ $t = 1$
- ☐ $t = -2xy$

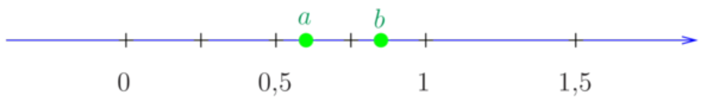
☐ Der Ausdruck kann nicht vereinfacht werden, $t = \dfrac{(x-y)^2}{x^2-y^2}$.

***Lösung:***

☑ $t = \dfrac{x-y}{x+y}$

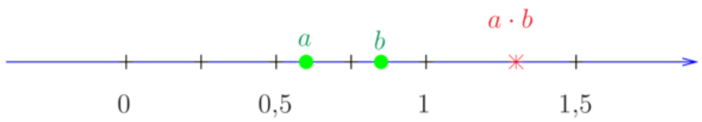
***Aufgabenname:*** *ari_bru_gen_107*

**Aufgabe 1.3.** Die Zahlen $a$ und $b$ haben die folgende Position auf dem Zahlenstrahl:

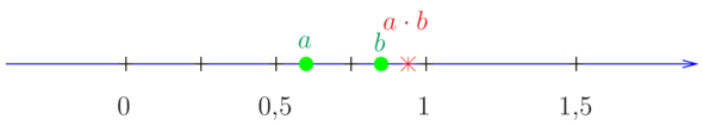



Welche Position hat $a \cdot b$?

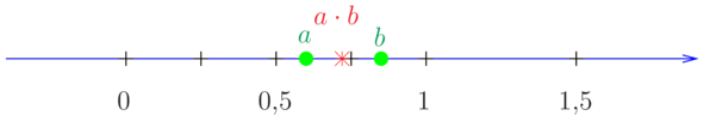
☐ Der Punkt $a \cdot b$ hat in etwa folgende Lage auf dem Zahlenstrahl



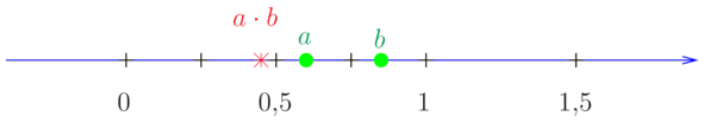

☐ Der Punkt $a \cdot b$ hat in etwa folgende Lage auf dem Zahlenstrahl



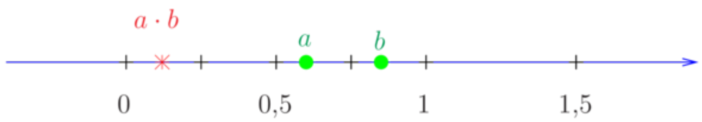
□ Der Punkt $a \cdot b$ hat in etwa folgende Lage auf dem Zahlenstrahl




□ Der Punkt $a \cdot b$ hat in etwa folgende Lage auf dem Zahlenstrahl




□ Der Punkt $a \cdot b$ hat in etwa folgende Lage auf dem Zahlenstrahl




***Aufgabenname:*** *ari_pro_gen_108*

**Aufgabe 1.4.** Eine Zahl $b$ ist 100% größer als die Zahl $a$.
Um wie viel % ist $a$ kleiner als $b$?

| %

***Lösung:***

50 %

***Aufgabenname:*** *ari_pro_gen_103*

**Aufgabe 1.5.** Der Mehrwertsteuersatz in einem Land wird von 20 % auf 25 % erhöht. Wie viel kostet ein Produkt, das vorher (inklusive Mehrwertsteuer) 480 €, gekostet hat, nach der Mehrwertsteuererhöhung, wenn die Erhöhung voll an die Kunden weitergegeben wird?

| €|
|---|

***Lösung:*** *500 €*

## 2 Gleichungen I

***Aufgabenname:*** *gle_lin_gen_111*

**Aufgabe 2.1.** Ein Mobilfunkprovider bietet zwei Tarife an, einen Basistarif mit einer Grundgebühr von 3,99 € pro Monat, bei dem jede begonnen Minute 0,13 € kostet, und eine Flatrate von 24,49 € pro Monat mit unbegrenzten Gesprächen.

Wie viele Minuten mindestens telefoniert werden, damit sich die Flatrate lohnt? (Runden Sie Ihr Ergebnis auf ganze Minuten.)

| Minuten|
|---|

***Lösung:***

| *158 Minuten* |
|---|

***Aufgabenname:*** *gle_lin_gen_106*

**Aufgabe 2.2.** Ein Kilogramm Kirschen kostet dreimal so viel wie ein Kilogramm Aprikosen.
Wie viel kosten fünf Kilogramm Aprikosen, wenn zwei Kilogramm Kirschen 24 € kosten?

| €|
|---|

***Lösung:*** *20 €*

***Aufgabenname:*** *gle_lin_gen_107*

**Aufgabe 2.3.** Ein vollbeladener LKW wiegt $x$ Tonnen. Wenn er zur Hälfte beladen ist, wiegt er $y$ Tonnen.
Wie viele Tonnen wiegt der leere LKW?

- ☐ $\frac{x-y}{2}$ Tonnen.
- ☐ $x - y$ Tonnen.
- ☐ $x - 2y$ Tonnen.
- ☐ $2y - x$ Tonnen.
- ☐ $2x - 2y$ Tonnen.

***Lösung:***

- ☑ $2y - x$ *Tonnen*

***Aufgabenname:*** *gle_qug_gen_101*

**Aufgabe 2.4.** Bestimmen Sie die Lösungen der quadratischen Gleichung $x^2 - 3x + 2 = 0$ und ordnen Sie diese der Größe nach (so dass also $x_1 \leq x_2$).

$\boxed{x_1 = \quad 1}$ $\boxed{x_2 = \quad 2}$

***Lösung:*** $x_1 = 1$ $x_2 = 2$

# 3 Potenzen, Wurzeln, Logarithmen I

***Aufgabenname:*** *pwl_wur_gen_103*

**Aufgabe 3.1.** Ein quaderförmiger Steinblock mit quadratischer Grundfläche ist dreimal so hoch wie breit und hat ein Volumen von $192\,m^3$.
Wie breit ist der Steinblock?

$\boxed{\quad \text{Meter}}$

***Lösung:*** $4$ *Meter*

***Aufgabenname:*** *pwl_wur_wur_101*

**Aufgabe 3.2.** Welche der folgenden Rechenregeln für Wurzeln ist richtig?

- ☐ $\sqrt{ab} = \sqrt{a} + \sqrt{b}$
- ☐ $\sqrt{a+b} = \sqrt{a} + \sqrt{b}$
- ☐ $\sqrt{\frac{a}{b}} = \frac{\sqrt{b}}{\sqrt{a}}$
- ☐ $\sqrt{ab} = \sqrt{a} \cdot \sqrt{b}$
- ☐ $\sqrt{a+b} = \sqrt{a} \cdot \sqrt{b}$

***Lösung:***

- ☑ $\sqrt{ab} = \sqrt{a} \cdot \sqrt{b}$

***Aufgabenname:*** *pwl_gan_gen_102*

**Aufgabe 3.3.** Für welchen ganzzahligen Exponenten $n$ gilt $2^{-n} = 16$?

***Lösung:*** $n = -4$

***Aufgabenname:*** *pwl_gan_gen_103*

**Aufgabe 3.4.** Welches ist die kleinste ganze Zahl $n$, für die $3^{-n} \leq 10$ gilt?

***Lösung:*** $n = -2$

***Aufgabenname:*** *pwl_log_gen_130*

**Aufgabe 3.5.** Was ist $\log_4(64)$?

*Lösung:*

$\boxed{3}$

# 4 Funktionen I

*Aufgabenname: fun_for_gen_101*

**Aufgabe 4.1.** Was ist die korrekte Definition einer Funktion $f: M \longrightarrow N$?

- ☐ Eine Funktion $f: M \longrightarrow N$ ist eine Beziehung, die jedem $n \in N$ genau ein $m \in M$ zuordnet.
- ☐ Eine Funktion $f: M \longrightarrow N$ ist eine Beziehung, die jedem $m \in M$ genau ein $n \in N$ zuordnet.
- ☐ Eine Funktion $f: M \longrightarrow N$ ist eine Beziehung, die jedem $m \in M$ mindestens ein $n \in N$ zuordnet.
- ☐ Eine Funktion $f: M \longrightarrow N$ ist eine Beziehung, die ausgewählten $m \in M$ genau ein $n \in N$ zuordnet.
- ☐ Eine Funktion $f: M \longrightarrow N$ ist eine Beziehung, die ausgewählte Elemente $m \in M$ mit ausgewählten Elementen $n \in N$ verbindet.

*Lösung:*

- ☑ *Eine Funktion $f: M \longrightarrow N$ ist eine Beziehung, die jedem $m \in M$ genau ein $n \in N$ zuordnet.*

*Aufgabenname: fun_lin_gen_105*

**Aufgabe 4.2.** Wir betrachten die lineare Funktion $f(x) = ax + b$ mit $a \neq 0$.
An welcher Stelle schneidet der Graph der Funktion die $x$-Achse?

☐ $x = b$

☐ $x = a$

☐ $x = -a$

☐ $x = -\frac{b}{a}$

☐ Das kann man an der Funktionsvorschrift so allgemein nicht ablesen.

***Lösung:***

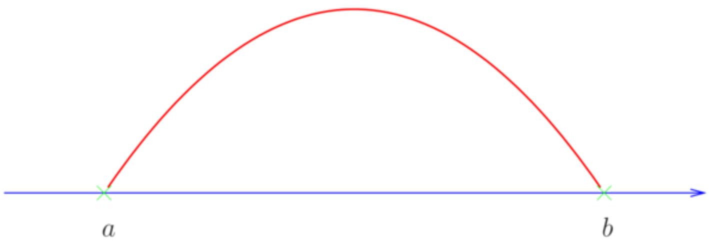
☑ $x = -\frac{b}{a}$

***Aufgabenname:*** *fun_qua_gen_106*

**Aufgabe 4.3.** Die Flughöhe eines Fußballs (in Metern über dem Fußballplatz) ist gegeben durch die Formel

$$h(t) = 20t - 5t^2$$

wobei $t$ die Zeit in Sekunden nach dem Abschlag ist.




Wie viele Sekunden nach dem Abschlag kommt der Ball wieder am Boden an?

***Lösung:***

$\boxed{4}$

***Aufgabenname:*** *fun_exp_gen_110*

**Aufgabe 4.4.** Auf Meereshöhe beträgt der Luftdruck der Erdatmosphäre $1\,013\,hPa$ (Hektopascal). Als Funktion der Höhe über dem Meeresspiegel lässt sich der Luftdruck durch folgende Funktion beschreiben:

$$p(h) = 1\,013 \cdot 0{,}88249^h$$

wobei $h$ die Höhe über dem Meeresspiegel in $km$ bezeichnet und $p = p(h)$ den Luftdruck in Hektopascal.
In welcher Höhe befinden wir uns, wenn ein Luftdruck von $400\,hPa$ herrscht?

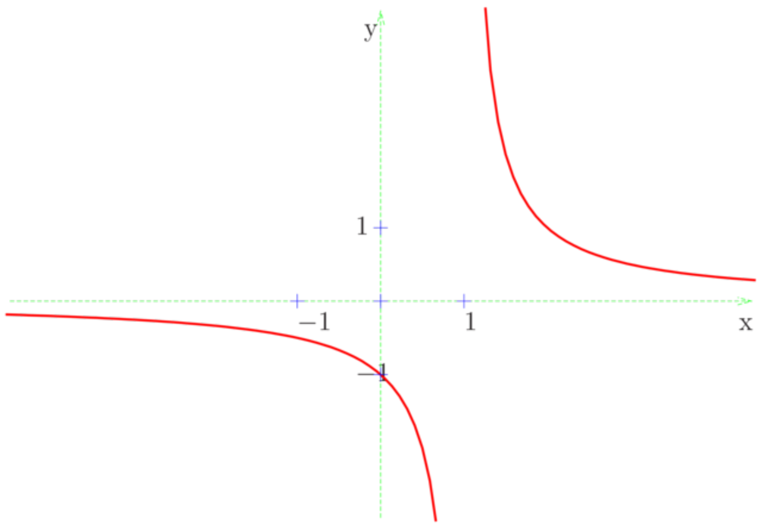
- ☐ ca. $450\,m$
- ☐ ca. $7\,450\,m$
- ☐ ca. $4\,500\,m$
- ☐ ca. $7{,}45\,m$
- ☐ ca. $745\,m$
- ☐ ca. $5\,000\,m$

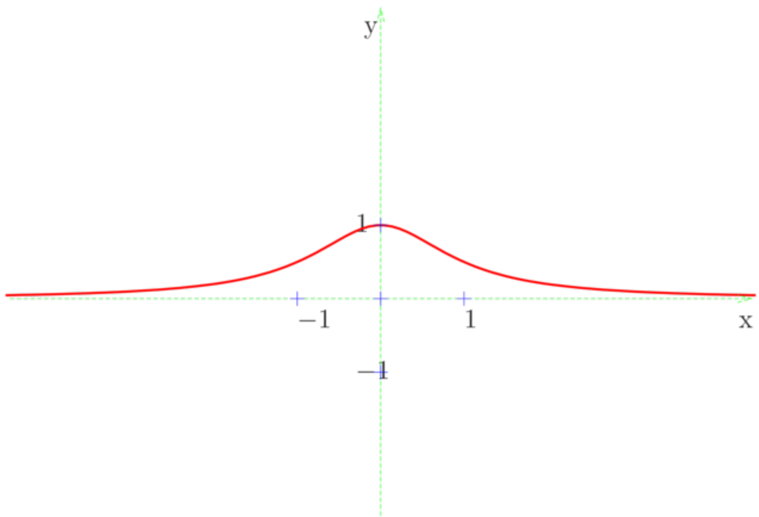
***Lösung:***

- ☑ *ca.* $7\,450\,m$

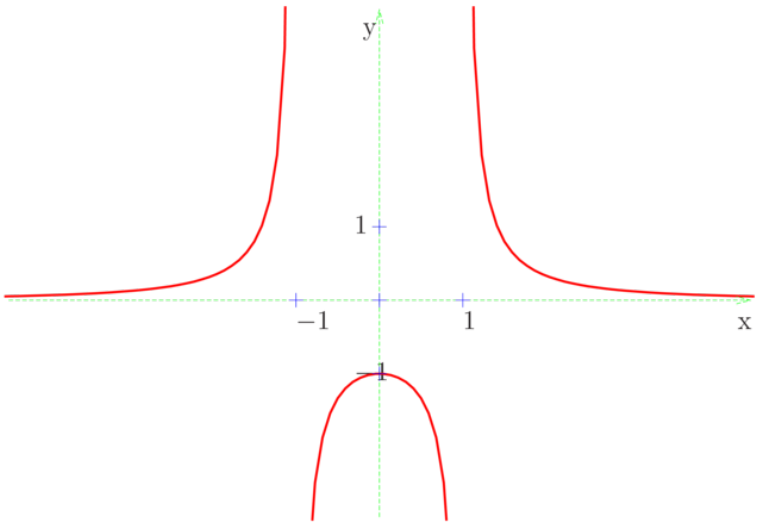
***Aufgabenname:*** *fun_gra_gen_107*

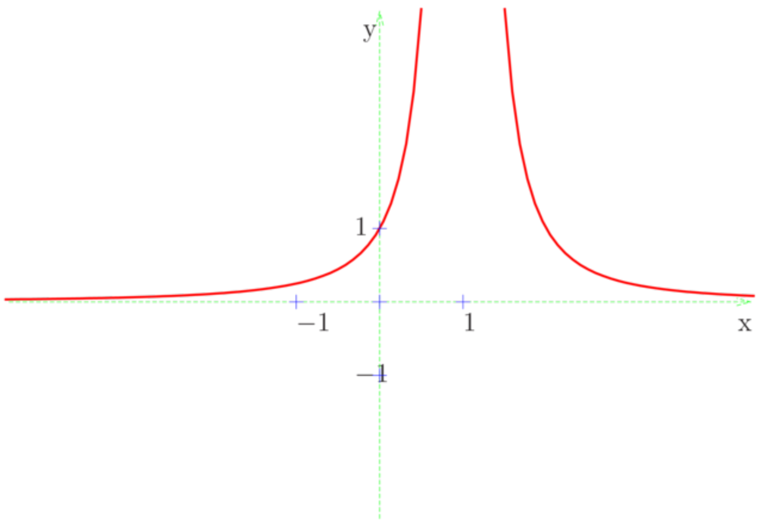
**Aufgabe 4.5.** Welcher der folgenden Graphen gehört zur Funktion $f(x) = \frac{1}{x^2-1}$?


y
1
−1
1
x
−1


y
1
−1
1
x
−1

Lösung:




- ☐ Graph 1.
- ☐ Graph 2.
- ☐ Graph 3.
- ☐ Graph 4.

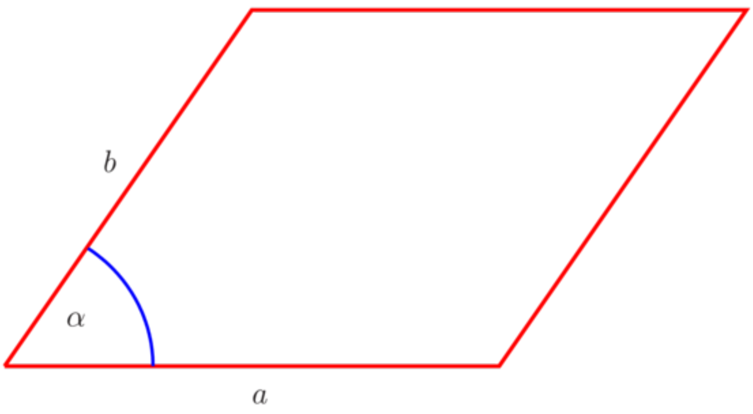
**Lösung:**

☑ *Graph 3.*

## 5 Geometrie I

***Aufgabenname:*** *geo_fla_par_102*

**Aufgabe 5.1.** Wir betrachten ein Parallelogramm wie folgt:




Es ist bekannt, dass die beiden Seiten die Länge $a = 4{,}0\,m$ und $b = 3{,}5\,m$ haben und dass für den Winkel $\alpha$ gilt: $\alpha = 60°$.

Was können wir über den Flächeninhalt $A$ sagen?

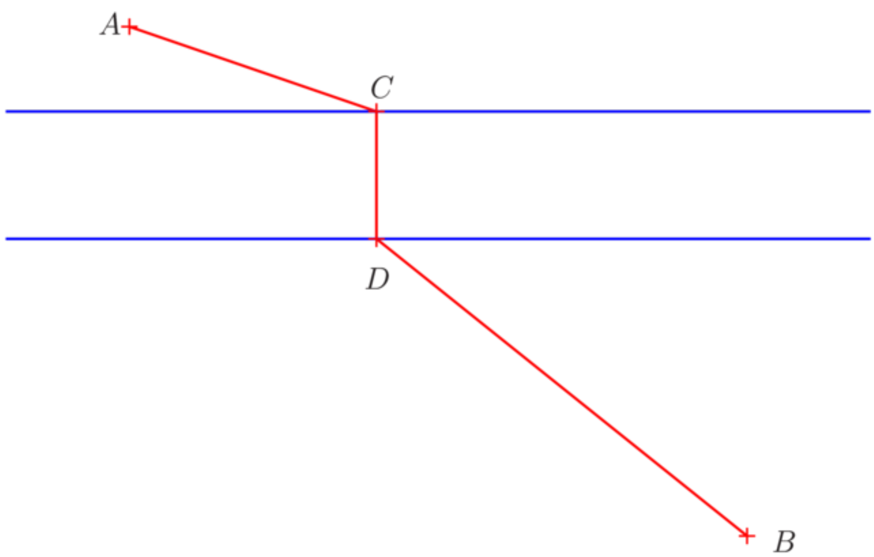
- ☐ $A = 14\,m^2$.
- ☐ $A \approx 12\,m^2$.
- ☐ $A > 14\,m^2$.
- ☐ $A < 10\,m^2$.
- ☐ $A$ kann aus den gegebenen Daten nicht bestimmt werden.

**Lösung:**

☑ $A \approx 12\,m^2$

**Aufgabenname:** *geo_str_gen_107*

**Aufgabe 5.2.** Die beiden Städte $A$ und $B$ liegen auf verschiedenen Seiten eines Kanals (mit genau parallelen Ufern), liegen sich aber nicht direkt gegenüber. Es soll nun eine Brücke über den Kanal zwischen einem Punkt $C$ und dem genau gegenüberliegenden Punkt $D$ gebaut werden.




Wie ist $C$ zu wählen, damit die Wegstrecke zwischen $A$ und $B$ minimiert wird?

☐ $A$ liegt näher am Kanal als $B$, also ist $C$ so zu wählen, dass $\overline{AC}$ senkrecht zum Kanal steht.

☐ $A$ liegt näher am Kanal als $B$, also ist $C$ so zu wählen, dass $\overline{DB}$ senkrecht zum Kanal steht.

☐ $C$ ist so zu wählen, dass $\overline{AC}$ und $\overline{DB}$ parallel sind.

☐ Es ist egal, wie $C$ gewählt wird, die Entfernung ist unabhängig von der Wahl von $C$.

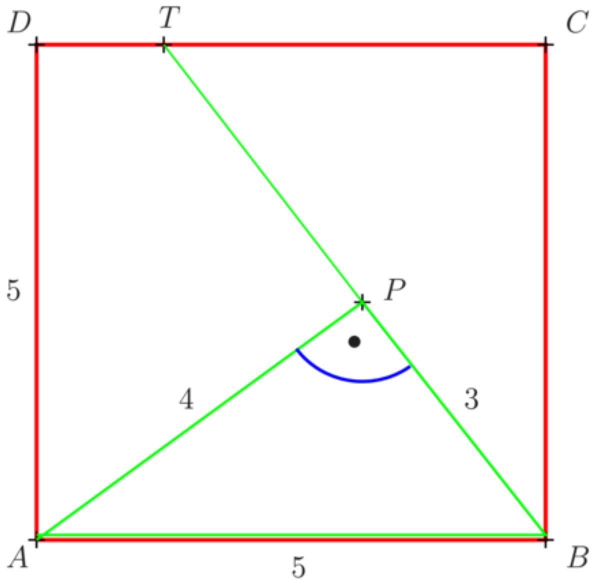
- ☐ Der Punkt $C$ ist so zu wählen, dass er genau in der Mitte zwischen $A$ und $B$ liegt (entlang des Kanals gemessen).
- ☐ Eine allgemeine Aussage kann nicht getroffen werden.

**Lösung:**

- ☑ *$C$ ist so zu wählen, dass $\overline{AC}$ und $\overline{DB}$ parallel sind.*

***Aufgabenname:*** *geo_aeh_gen_101*

**Aufgabe 5.3.** Wir betrachten ein Quadrat $ABCD$ mit Seitenlänge 5. In dieses Quadrat wird ein Punkt $P$ eingezeichnet, so dass $ABP$ ein rechtwinkliges Dreieck mit Hypotenuse $AB$ und den beiden Katheten $AP$ der Länge 4 und $BP$ der Länge 3 bildet. Die Linie $BP$ wird verlängert bis sie $CD$ im Punkt $T$ schneidet.




Wie lange ist das Geradenstück $TC$?

- ☐ $\frac{13}{4}$
- ☐ 4

☐ 5

☐ $\frac{17}{4}$

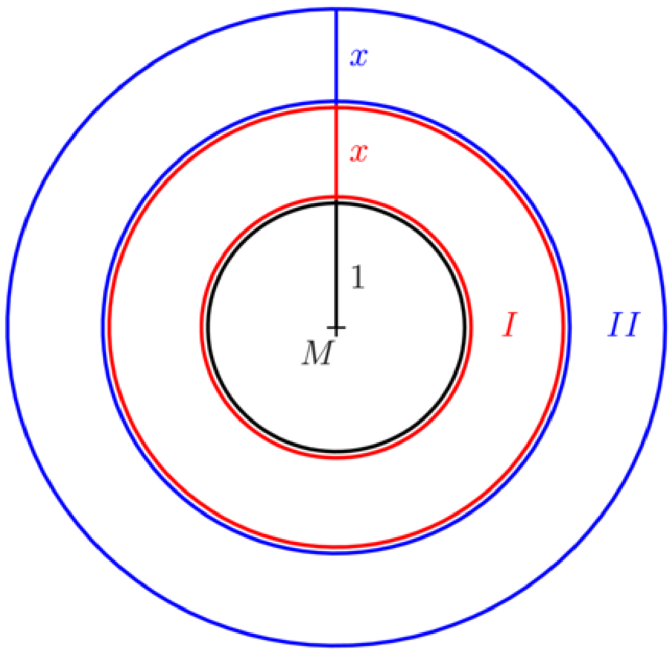
☐ $\frac{15}{4}$

***Lösung:***

☑ $\frac{15}{4}$

***Aufgabenname:*** *geo_kre_gen_106*

**Aufgabe 5.4.** Wir betrachten drei konzentrische Kreise mit Mittelpunkt $M$ und den Radien $r_1 = 1$, $r_2 = 1 + x$ und $r_3 = 1 + 2x$.




Wie groß muß $x$ sein, damit die Fläche des äußeren Kreisrings $II$ doppelt so groß ist wie die des mittleren Kreisrings $I$?

☐ $x = \frac{1}{3}$

☐ $x = \frac{1}{2}$

☐ $x = 3$

☐ $x = 2$

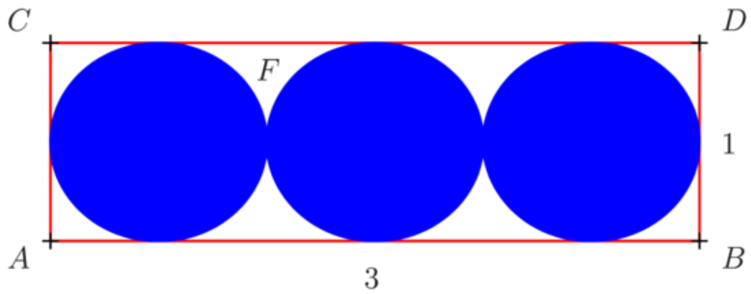
☐ $x = 1$

***Lösung:***

☑ $x = 2$

***Aufgabenname:*** *geo_kre_gen_107*

**Aufgabe 5.5.** Aus einem Rechteck mit den Seitenlängen 1 und 3 Längeneinheiten werden 3 nebeneinanderliegende und sich berührende Kreise mit maximalem Radius herausgeschnitten.




Welche Fläche $F$ bleibt übrig?

☐ $F = 3 \cdot (1 - \pi)$

☐ $F = 3 \cdot (1 - \frac{\pi}{2})$

☐ $F = 3 \cdot (1 - \frac{\pi}{4})$

☐ $F = 3 \cdot (\frac{\pi}{2} - 1)$

☐ $F = 3 \cdot (\pi - 1)$

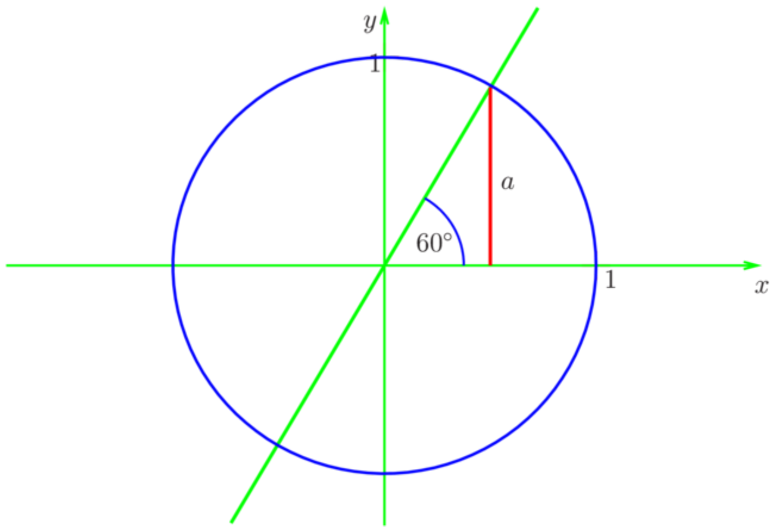
***Lösung:***

☑ $F = 3 \cdot (1 - \frac{\pi}{4})$

# 6 Trigonometrie I

***Aufgabenname:*** *tri_fun_gen_104*

**Aufgabe 6.1.** Die Werte trigonometrischer Funktionen lassen sich im Einheitskreis als Abschnitte bestimmter Geraden konstruieren. Wir betrachten den Winkel $\alpha = 60°$.




Dann gilt:

☐ $a = \tan(60°)$

☐ $a = \sin(60°)$

☐ $a = \cos(60°)$

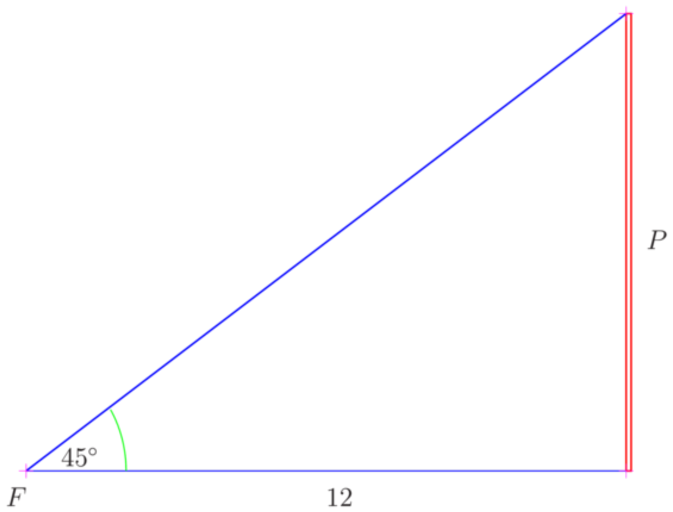
☐ $a = \cot(60°)$

***Lösung:***

☑ $a = \sin(60°)$

***Aufgabenname:*** *tri_fun_gen_129*

**Aufgabe 6.2.** Ein Frosch ist 12 $m$ vom Fußpunkt eines senkrecht eingeschlagenen Pfahls entfernt. Er sieht die Spitze des Pfahls $P$ unter einem Winkel von 45°.




Wie hoch ist der Pfahl (Höhe in Meter, gerundet auf zwei Stellen hinter dem Komma)?

| $m$ |
|---|

***Lösung:***

| 12 $m$ |
|---|

***Aufgabenname:*** *tri_fun_gen_106*

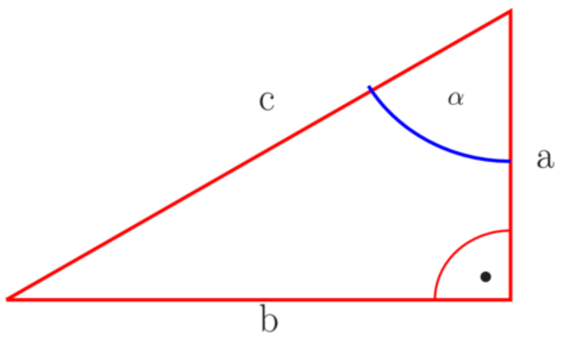
**Aufgabe 6.3.** Bestimmen Sie, ob der folgende Ausdrucke positiv (+) oder negativ (-) ist oder ob sie verschwinden (0) oder nicht definiert sind (n):

$\tan(300°)$

**Lösung:** $\tan(300°)$

**Aufgabenname:** *tri_fun_gen_107*

**Aufgabe 6.4.** Wir betrachten ein rechtwinkliges Dreieck mit einem Winkel $\alpha$ wie folgt:




Welche der folgenden Aussagen ist richtig?

- ☐ $\tan(\alpha) = \frac{b}{a}$
- ☐ $\sin(\alpha) = \frac{b}{a}$
- ☐ $\cos(\alpha) = \frac{b}{a}$
- ☐ $\cot(\alpha) = \frac{b}{a}$

**Lösung:**

- ☑ $\tan(\alpha) = \frac{b}{a}$

# 7 Logik und Kombinatorik I

***Aufgabenname:*** *log_kom_gen_107*

**Aufgabe 7.1.** Ein Auto ist in 3 Modellvarianten verfügbar, und jede Variante gibt es in 7 Farben.

Wie viele Modell–Farbkombinationen sind möglich?

***Lösung:***

21

***Aufgabenname:*** *log_kom_gen_109*

**Aufgabe 7.2.** In einem Topf befinden sich sechs Zettel mit den Ziffern $1, \ldots, 6$. Anna zieht zwei Zettel und legt sie in aufsteigender Reihenfolge der Ziffern aneinander.

Wie viele zweistellige Zahlen kann Sie auf diese Art und Weise bekommen?

***Lösung:***

15

***Aufgabenname:*** *log_kom_gen_111*

**Aufgabe 7.3.** Vier Kunden einer Firma sollen eine Rechnung über jeweils unterschiedliche Beträge erhalten. Die Sekretärin passt jedoch nicht auf und schreibt die vier Namen willkürlich auf die Rechnungen. Die Hilfskraft steckt die Rechnungen unabhängig davon zufällig in je einen (schon beschrifteten) Umschlag.

Wie groß ist die Wahrscheinlichkeit $p$, dass jeder Kunde die richtige Rechnung (mit dem richtigen Betrag und dem richtigen Namen) erhält?

- ☐ $p = \frac{1}{64}$.

☐ $p = \frac{1}{4}$.

☐ $p = \frac{1}{16}$.

☐ $p = \frac{1}{24}$.

☐ $p = \frac{1}{(24)^2}$.

☐ $p = \frac{1}{(24)^3}$.

***Lösung:***

☑ $p = \frac{1}{(24)^2}$.

***Aufgabenname:*** *log_wah_gen_106*

**Aufgabe 7.4.** Anton lügt montags, dienstags und mittwochs immer und an den anderen Tagen nie, Berta lügt donnerstags, freitags und samstags immer und an den anderen Tagen nie. Eines Tages sagt Anton zu Berta: ”Morgen werde ich lügen”. Berta erwidert: ”Ich werde morgen ebenfalls lügen”.
An welchem Tag fand dieses Gespräch statt?

☐ An einem Sonntag.

☐ An einem Montag.

☐ An einem Mittwoch.

☐ An einem Donnerstag.

☐ An einem Samstag.

☐ Der Wochentag lässt sich nicht eindeutig bestimmen.

***Lösung:***

☑ *An einem Mittwoch.*

## 8 Vektorrechnung I

*Aufgabenname:* lal_ana_ge2_101

**Aufgabe 8.1.** Berechnen Sie den Abstand $d$ des Punktes $P = (-\sqrt{2}, \sqrt{2})$ von der Geraden $G$ durch die Punkte $A = (1,\ 1)$ und $B = (2,\ 2)$.

$d =$ $\boxed{\phantom{xxxx}}$

*Lösung:*

$d =$ $\boxed{2}$

*Aufgabenname:* lal_ana_ge3_102

**Aufgabe 8.2.** Die Gerade $G_1$ geht durch die Punkte $A = (1,\ 2,\ 3)$ und $B = (3,\ 2,\ 1)$ und die Gerade $G_2$ ist gegeben durch:

$$G_2 : \begin{pmatrix} 3 \\ 3 \\ 3 \end{pmatrix} + \lambda \cdot \begin{pmatrix} -2 \\ 0 \\ 2 \end{pmatrix}$$

Dann gilt:

- ☐ $G_1 = G_2$.
- ☐ $G_1$ und $G_2$ sind parallel (aber nicht gleich).
- ☐ $G_1$ und $G_2$ sind windschief.
- ☐ $G_1$ und $G_2$ schneiden sich in genau einem Punkt
- ☐ Aus den Angaben kann man die Lage von $G_1$ und $G_2$ zueinander nicht ablesen.

*Lösung:*

- ☑ *$G_1$ und $G_2$ sind parallel (aber nicht gleich).*

*Aufgabenname:* lal_ana_abs_gee_102

**Aufgabe 8.3.** Die Gerade $G$ geht durch die Punkte $A = (2,\, 2,\, 2)$ und $B = (2,\, 3,\, 4)$ und die Ebene $E$ geht durch die Punkte $C = (1,\, 1,\, 1)$, $D = (1,\, 1,\, 2)$ und $E = (2,\, 1,\, 1)$.

Dann gilt:

- ☐ $G$ ist in $E$ enthalten.
- ☐ $G$ ist parallel zu $E$ mit Abstand $d < 1$ (Längeneinheit).
- ☐ $G$ ist parallel zu $E$ mit Abstand $d > 1$ (Längeneinheit).
- ☐ $G$ ist parallel zu $E$ mit Abstand $d = 1$ (Längeneinheit).
- ☐ $G$ und $E$ schneiden sich in genau einem Punkt

***Lösung:***

- ☑ *$G$ und $E$ schneiden sich in genau einem Punkt*

***Aufgabenname:*** *lal_gls_lin_101*

**Aufgabe 8.4.** Ein Kilogramm Äpfel kostet 2 €, ein Kilogramm Pfirsiche kostet 4 €.

Wie viele Kilogramm Äpfel haben Sie gekauft, wenn Sie insgesamt 14 Kilogramm Obst gekauft haben und dafür 38 € gezahlt haben?

☐ Kilogramm Äpfel

***Lösung:***

$\boxed{9}$ *Kilogramm Äpfel*

# 9 Arithmetik II

***Aufgabenname:*** *ari_ter_kla_102*

**Aufgabe 9.1.** Vereinfachen Sie den folgenden Ausdruck durch Ausklammern, Ausmultiplizieren und Kürzen so weit, wie möglich:

$$t = (2x + 3y)^2 - (2x - 3y)^2$$

- ☐ $t = 12xy$
- ☐ $t = 8x^2 + 18y^2$
- ☐ $t = 24xy$
- ☐ $t = 18y^2$
- ☐ Der Ausdruck kann nicht vereinfacht werden, $t = (2x+3y)^2 - (2x-3y)^2$

***Lösung:***

- ☑ $t = 24xy$

***Aufgabenname:*** *ari_ter_bin_106*

**Aufgabe 9.2.** Vereinfachen Sie den folgenden Ausdruck durch Ausklammern, Ausmultiplizieren und Kürzen soweit, wie möglich:

$$t = \frac{x^3 - 1}{x^2 - 1}$$

(Hinweis: $x = 1$ ist eine Lösung von $x^3 - 1 = 0$ und von $x^2 - 1 = 0$).

- ☐ Der Ausdruck kann nicht vereinfacht werden, $t = \dfrac{x^3 - 1}{x^2 - 1}$
- ☐ $t = \dfrac{x^2 - 1}{x - 1}$
- ☐ $t = \dfrac{x^2 + 1}{x + 1}$
- ☐ $t = \dfrac{x^2 + x + 1}{x + 1}$
- ☐ $t = x^3 - x^2$

***Lösung:***

- ☑ $t = \dfrac{x^2 + x + 1}{x + 1}$

***Aufgabenname:*** *ari_pro_gen_104*

**Aufgabe 9.3.** Ein Arbeiter verdient brutto 16 € in der Stunde. Nach einer Beförderung erhält er einen Stundenlohn von 17,12 €.
Um wie viel Prozent ist sein Stundenlohn gestiegen?

| |
|---|
| |

***Lösung:***

| |
|---|
| *7* |

***Aufgabenname:*** *ari_pro_gen_105*

**Aufgabe 9.4.** Wie viel sind 25% von 25% von $x$?

- ☐ $\frac{x}{4}$
- ☐ $\frac{x}{16}$
- ☐ $\frac{x}{2}$
- ☐ $\frac{x}{25}$
- ☐ $\frac{x}{125}$
- ☐ $\frac{x}{625}$

***Lösung:***

- ☑ $\frac{x}{16}$

***Aufgabenname:*** *ari_pro_gen_106*

**Aufgabe 9.5.** Eine Bakterienkultur wächst in der ersten Stunde um 10 %, nimmt in der zweiten Stunde um 10 % ab, wächst dann wieder um 10 %, nimmt dann wieder um 10 % ab usw. In jeder ungeraden Stunde nimmt die Anzahl der Bakterien also um 10 % zu (im Vergleich zum Wert zu Beginn dieser Stunde), in jeder geraden Stunde nimmt sie um 10 % ab (im Vergleich zum Wert zu Beginn dieser Stunde).
Wie entwickelt sich die Bakterienpopulation langfristig:

- ☐ Sie pendelt immer gleichmäßig um den Ausgangswert und weicht um höchstens 10% vom ihm ab.
- ☐ Sie steigt im Laufe der Zeit an und wächst über alle Schranken.
- ☐ Sie fällt im Laufe der Zeit ab und die Kultur verschwindet langfristig.
- ☐ Die Schwankungen in der Population nehmen im Laufe der Zeit immer mehr zu.
- ☐ Sie stabilisiert sich im Laufe der Zeit beim Ausgangswert.

***Lösung:***

- ☑ *Sie fällt im Laufe der Zeit ab und die Kultur verschwindet langfristig.*

# 10 Gleichungen II

***Aufgabenname:*** *gle_lin_gen_108*

**Aufgabe 10.1.** Zwei Pumpen leeren einen Behälter mit Wasser in vier Stunden. Dabei pumpt die stärkere der beiden Pumpen dreimal so viel Wasser wie die schwächere. Wie lange braucht die schwächere allein, um den Behälter leer zu pumpen?

| Stunden |
|---|

***Lösung:***

| *16 Stunden* |
|---|

***Aufgabenname:*** *gle_qug_gen_102*

**Aufgabe 10.2.** Wir betrachten eine allgemeine quadratische Gleichung $ax^2+bx+c=0$. Welche Aussage ist richtig:

- ☐ Die Gleichung hat immer zwei reelle Lösungen.
- ☐ Die Gleichung hat zwei Lösungen, wenn $b^2-4ac>0$ ist, andernfalls gibt es keine (reellen) Lösungen.

☐ Die Gleichung hat zwei Lösungen, wenn $b^2 - 4ac \geq 0$ ist, andernfalls gibt es keine (reellen) Lösungen.

☐ Die Gleichung hat zwei Lösungen, wenn $b^2 - 4ac > 0$ ist, sie hat eine Lösung, wenn $b^2 - 4ac = 0$, und andernfalls gibt es keine (reellen) Lösungen.

☐ Das kann man nur entscheiden, wenn konkrete Werte für $a$, $b$ und $c$ gegeben sind.

***Lösung:***

☑ *Die Gleichung hat zwei Lösungen, wenn $b^2 - 4ac > 0$ ist, sie hat eine Lösung, wenn $b^2 - 4ac = 0$, und andernfalls gibt es keine (reellen) Lösungen.*

***Aufgabenname:*** *gle_qug_gen_103*

**Aufgabe 10.3.** Das Produkt zweier positiver ganzer Zahlen, von denen die eine um 2 größer ist als die andere, ist 48.
Wie lautet die kleinere der beiden Zahlen?

[ ]

***Lösung:***

[ *6* ]

***Aufgabenname:*** *gle_qug_gen_104*

**Aufgabe 10.4.** Ein rechteckiges Grundstück, das zweimal so lang wie breit ist, hat eine Fläche von $722\,m^2$.
Wie breit ist das Grundstück?

[ Meter ]

***Lösung:***

[ *19 Meter* ]

***Aufgabenname:*** *gle_qug_gen_107*

**Aufgabe 10.5.** Wir betrachten eine quadratische Gleichung

$$2x^2 - 8x + a = 0$$

Wie ist $a$ zu wählen, damit diese Gleichung genau eine (doppelte) Lösung hat?

$a =$ $\boxed{\phantom{00}}$

***Lösung:***

$a =$ $\boxed{8}$

# 11 Potenzen, Wurzeln, Logarithmen II

***Aufgabenname:*** *pwl_log_log_101*

**Aufgabe 11.1.** Berechnen Sie $\ln(3e^4) + \ln\left(\frac{e}{3}\right)$:

$\boxed{\phantom{00}}$

***Lösung:***

$\boxed{5}$

***Aufgabenname:*** *pwl_log_log_104*

**Aufgabe 11.2.** Die Anzahl der Schimmelpilze in einem verdorbenen Stück Brot vervierfacht sich jeden Tag.

Wie viel Zeit ist vergangen, wenn sich seit Beginn des Befalls die Anzahl der Schimmelpilze verachtfacht hat?

(Geben Sie das Ergebnis in Tagen an, gerundet auf zwei Stellen nach dem Komma)?

$\boxed{\phantom{00}}$

***Lösung:***

*Aufgabenname: pwl_log_log_103*

**Aufgabe 11.3.** Welche der folgenden Rechenregeln für Logarithmen ist richtig?

- ☐ $\ln(a \cdot b) = \ln(a) \cdot \ln(b)$
- ☐ $\ln(\frac{a}{b}) = \ln(a) \cdot \ln(b)$
- ☐ $\ln(a + b) = \ln(a) \cdot \ln(b)$
- ☐ $\ln(a \cdot b) = \ln(a) + \ln(b)$
- ☐ $\ln(a + b) = \ln(a) + \ln(b)$

***Lösung:***

- ☑ $\ln(a \cdot b) = \ln(a) + \ln(b)$

*Aufgabenname: pwl_gan_gen_105*

**Aufgabe 11.4.** Die Hälfte $s$ von $t = 4^8$ ist

- ☐ $s = 2^4$
- ☐ $s = 2^{15}$
- ☐ $s = 4^7$
- ☐ $s = 4^4$
- ☐ $s = 2^8$

***Lösung:***

- ☑ $s = 2^{15}$

# 12 Funktionen II

***Aufgabenname:*** *fun_qua_gen_107*

**Aufgabe 12.1.** Welche der folgenden Funktionen beschreibt eine Normalparabel mit Scheitel im Punkt $(1, 0)$?

- ☐ $f(x) = x^2 + 2$
- ☐ $f(x) = x^2 + 2x + 1$
- ☐ $f(x) = x^2 + x + 2$
- ☐ $f(x) = x^2 - x + 2$
- ☐ $f(x) = x^2 - 2x + 1$

***Lösung:***

- ☑ $f(x) = x^2 - 2x + 1$

***Aufgabenname:*** *fun_rat_gen_103*

**Aufgabe 12.2.** Welche der folgenden Aussagen ist richtig für die Funktion

$$f(x) = \frac{x^2 - 5x + 6}{x^2 - 1}$$

- ☐ $f$ hat Definitionslücken in $-1$ und in $1$ und keine Nullstellen.
- ☐ $f$ hat eine Definitionslücke in $1$, keine weiteren Definitionslücken und Nullstellen in $2$ und $3$.
- ☐ $f$ hat eine Definitionslücke in $1$, keine weiteren Definitionslücken und Nullstellen in $-2$ und $-3$.
- ☐ $f$ hat Definitionslücken in $-1$ und in $1$, keine weiteren Definitionslücken und Nullstellen in $2$ und $3$.
- ☐ $f$ hat keine Definitionslücken und Nullstellen in $2$ und $3$.

***Lösung:***

- ☑ *$f$ hat Definitionslücken in $-1$ und in $1$, keine weiteren Definitionslücken und Nullstellen in $2$ und $3$.*

***Aufgabenname:*** *fun_mon_gen_102*

**Aufgabe 12.3.** Welche der folgenden Aussagen ist richtig für die Funktion

$$f(x) = x^3 + x$$

- ☐ $f$ ist streng monoton steigend und achsensymmetrisch.
- ☐ $f$ ist streng monoton steigend und punktsymmetrisch.
- ☐ $f$ ist streng monoton fallend und achsensymmetrisch.
- ☐ $f$ ist streng monoton fallend und punktsymmetrisch.
- ☐ $f$ ist weder streng monoton steigend oder fallend noch achsen- oder punktsymmetrisch.
- ☐ $f$ ist streng monoton steigend aber weder achsen- noch punktsymmetrisch.

***Lösung:***

- ☑ *$f$ ist streng monoton steigend und punktsymmetrisch.*

***Aufgabenname:*** *fun_exp_gen_112*

**Aufgabe 12.4.** Ein tropischer Regenwald wird durch Brandrodung zerstört. Von der gegenwärtig vorhandenen Waldfläche $W_0 = 325\,000\,km^2$ stehen $W_N = 25\,000\,km^2$ unter Naturschutz. Vom Rest gehen jährlich jeweils 5% (vom Anfangsbestand zu Beginn des jeweiligen Jahres) verloren.
Welche Vorschrift $W(t)$ beschreibt den Waldbestand als Funktion der Zeit, gemessen in Jahren von jetzt an?

- ☐ $W(t) = (W_0 - W_N) \cdot 0{,}95^t + W_N$
- ☐ $W(t) = W_0 \cdot 0{,}95^t + W_N$

☐ $W(t) = (W_0 - W_N) \cdot 0{,}05^t + W_N$

☐ $W(t) = (W_0 - W_N) \cdot e^{-0{,}95t} + W_N$

☐ $W(t) = W_0 - 0{,}05 \cdot W_0 \cdot t$

***Lösung:***

☑ $W(t) = (W_0 - W_N) \cdot 0{,}95^t + W_N$

# 13 Geometrie II

***Aufgabenname:*** *geo_for_gen_101*

**Aufgabe 13.1.** Welches der folgende Objekte existiert **nicht**?

☐ Ein Dreieck mit zwei 10°-Winkel.

☐ Ein Viereck mit zwei 10°-Winkel und einem 20°-Winkel.

☐ Ein rechtwinkliges Dreieck mit einem 10°-Winkel.

☐ Eine Raute mit einem 10°-Winkel.

☐ Ein Parallelogramm mit einem 10°-Winkel und einem 20°-Winkel.

***Lösung:***

☑ *Ein Parallelogramm mit einem 10°-Winkel und einem 20°-Winkel.*

***Aufgabenname:*** *geo_fla_dre_rec_104*

**Aufgabe 13.2.** Gegeben ist ein rechtwinkliges Dreieck, das einen spitzen Winkel von 45° enthält. Die Ankathete an diesen Winkel ist $8\,m$ lang.

Berechnen Sie den Flächeninhalt dieses Dreiecks.

$\boxed{\qquad\quad m^2}$

**Lösung:**

$\boxed{32\ m^2}$

*Aufgabenname:* *geo_str_gen_110*

**Aufgabe 13.3.** Ein $1,00\,m$ hoher, vertikal eingeschlagener Stab wirft einen Schatten von $1,20\,m$.
Wie hoch ist ein Baum, dessen Schatten zur selben Zeit $10,80\,m$ lang ist?

m

**Lösung:**

$\boxed{9\ m}$

*Aufgabenname:* *geo_ste_kug_102*

**Aufgabe 13.4.** Ein Kugel hat eine Masse von $2\,kg$.
Welche Masse hat eine Kugel aus demselben Material, wenn sie den Radius $2r$ hat?

kg

**Lösung:**

$\boxed{16\ kg}$

# 14 Trigonometrie II

*Aufgabenname:* *tri_fun_gen_109*

**Aufgabe 14.1.** Bestimmen Sie, ob der folgende Ausdruck positiv (+) oder negativ (-) ist oder ob er verschwinden (0) oder nicht definiert sind (n): $\cos\left(\frac{5\pi}{6}\right)$

**Lösung:** $\cos\left(\frac{5\pi}{6}\right)$

| - |
|---|

**Aufgabenname:** *tri_fun_gen_110*

**Aufgabe 14.2.** Bestimmen Sie, ob der folgende Ausdruck positiv (+) oder negativ (-) ist oder ob er verschwinden (0) oder nicht definiert sind (n):
$\cot(270°)$

| |
|---|

**Lösung:** $\cot(270°)$

| 0 |
|---|

**Aufgabenname:** *tri_fun_gen_111*

**Aufgabe 14.3.** Vom Winkel $\alpha$ wissen wir, dass $\sin(\alpha) > 0$ und $\cos(\alpha) < 0$.
Dann gilt:

- ☐ $0° < \alpha < 90°$
- ☐ $90° < \alpha < 180°$
- ☐ $180° < \alpha < 270°$
- ☐ $270° < \alpha < 360°$

**Lösung:**

- ☑ $90° < \alpha < 180°$

**Aufgabenname:** *tri_gle_gen_103*

**Aufgabe 14.4.** Für welche Zahlen $x \in [0, 5]$ gilt:

$$\cos\left(x - \frac{\pi}{4}\right) = 0$$

☐ $x = \frac{\pi}{4}$

☐ $x = \frac{3\pi}{4}$

☐ $x = \frac{5\pi}{4}$ und $x = \frac{7\pi}{4}$

☐ $x = \pi$

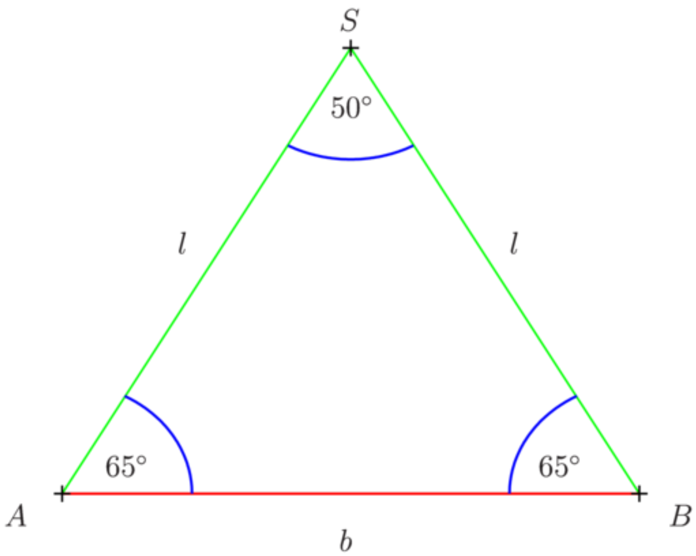
☐ $x = \frac{\pi}{2}$

***Lösung:***

☑ $x = \frac{3\pi}{4}$

***Aufgabenname:*** *tri_fun_gen_112*

**Aufgabe 14.5.** Eine Sprossen–Doppelleiter mit einfacher Leiterlänge $l = 1,25\,m$ wird so aufgestellt, dass die Seiten der Leiter einen Winkel von $50°$ bilden.




Nach welcher Formel berechnet sich die Breite $b$, die mindestens für das Aufstellen der Leiter benötigt wird?

- ☐ $b = 2l \cdot \tan(25°)$
- ☐ $b = 2l \cdot \sin(25°)$
- ☐ $b = 2l \cdot \sin(50°)$
- ☐ $b = l \cdot \cos(65°)$
- ☐ $b = 2l \cdot \tan(50°)$
- ☐ $b = l \cdot \cos(50°)$

***Lösung:***

- ☑ $b = 2l \cdot \sin(25°)$

# 15 Logik und Kombinatorik II

***Aufgabenname:*** *log_tau_gen_102*

**Aufgabe 15.1.** Eine bekannte Wetterregel besagt ”Kräht der Gockel auf dem Mist, so ändert sich das Wetter oder es bleibt wie es ist.”
Was ist von dieser Regel zu halten?

- ☐ Es handelt sich um blanken Unsinn.
- ☐ Die Regel ist tautologisch, also immer richtig.
- ☐ Die Regel stimmt nie.
- ☐ Die Regel stimmt manchmal, und sie stimmt manchmal nicht.
- ☐ Mit den Gesetzen der Logik kann man diese Regel nicht behandeln.

***Lösung:***

- ☑ *Die Regel ist tautologisch, also immer richtig.*

***Aufgabenname:*** *log_sch_gen_105*

**Aufgabe 15.2.** Welche der folgenden Schlussfolgerungen ist richtig?

- ☐ $x = 5 \Longrightarrow x^4 = 125$.
- ☐ $x^2 \geq 10 \Longrightarrow x \geq 5$.
- ☐ $x \geq 5 \Longrightarrow x^2 \geq 10$.
- ☐ $x^2 \geq 10 \Longrightarrow |x| \geq 5$.
- ☐ $x \in \mathbb{N}$ ungerade $\Longrightarrow x$ ist eine Primzahl.

***Lösung:***

- ☑ $x \geq 5 \Longrightarrow x^2 \geq 10$.

***Aufgabenname:*** *log_sch_gen_104*

**Aufgabe 15.3.** Im Land Verkehrtherum werden die Wochentage rückwärts gezählt, nach dem Sonntag kommt also der Samstag, dann der Freitag usw.
Wenn im Land Verkehrtherum der 1. Juli ein Samstag ist, welcher Tag ist dann der 31. Juli (im selben Jahr)?

- ☐ Sonntag
- ☐ Montag
- ☐ Dienstag
- ☐ Mittwoch
- ☐ Donnerstag
- ☐ Freitag

***Lösung:***

- ☑ *Donnerstag*

***Aufgabenname:*** *log_bew_gen_102*

**Aufgabe 15.4.** In der folgenden "Beweisführung" ist eine Schlussfolgerung falsch. Welche?

$$\begin{aligned} x < -2 &\overset{(1)}{\Longrightarrow} x + 1 < -1 \\ &\overset{(2)}{\Longrightarrow} (x+1)^2 > (-1)^2 = 1 \\ &\overset{(3)}{\Longrightarrow} x^2 + 2x > 0 \\ &\overset{(4)}{\Longrightarrow} x + 2 > 0 \\ &\overset{(5)}{\Longrightarrow} x > -2 \end{aligned}$$

Falsch ist

- ☐ Schritt (1).
- ☐ Schritt (2).
- ☐ Schritt (3).
- ☐ Schritt (4).
- ☐ Schritt (5).

***Lösung:***

- ☑ *Schritt (4).*

# 16 Vektorrechnung II

***Aufgabenname:*** *lal_vek_gen_111*

**Aufgabe 16.1.** Der Verbindungsvektor der Punkte $P$ und $Q$ hat die Koordinatendarstellung

$$\overrightarrow{PQ} = \begin{pmatrix} 2 \\ -5 \\ 2 \end{pmatrix}$$

und es ist $Q = (4, 3, -2)$. Dann gilt:

- ☐ $P = (6,\ -2,\ 0)$
- ☐ $P = (-2,\ -8,\ 4)$
- ☐ $P = (6,\ 8,\ 0)$
- ☐ $P = (2,\ 8,\ -4)$
- ☐ $P = (2,\ -2,\ -4)$

***Lösung:***

- ☑ $P = (2,\ 8,\ -4)$

***Aufgabenname:*** *lal_vek_gen_112*

**Aufgabe 16.2.** Wir betrachten die beiden Punkte $P = (1,\ 2,\ 3)$ und $Q = (3,\ 2,\ 1)$. Welcher der folgenden Vektoren steht senkrecht auf dem Verbindungsvektor $\vec{PQ}$ und hat die Länge 3?

- ☐ $\vec{v} = \begin{pmatrix} 2 \\ 1 \\ -2 \end{pmatrix}$
- ☐ $\vec{v} = \begin{pmatrix} 2 \\ 1 \\ 2 \end{pmatrix}$
- ☐ $\vec{v} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$
- ☐ $\vec{v} = \begin{pmatrix} 2 \\ -1 \\ 0 \end{pmatrix}$
- ☐ $\vec{v} = \begin{pmatrix} 1 \\ -2 \\ 2 \end{pmatrix}$

***Lösung:***

☑ $\vec{v} = \begin{pmatrix} 2 \\ 1 \\ 2 \end{pmatrix}$

***Aufgabenname:*** *lal_vek_ska_101*

**Aufgabe 16.3.** Wir betrachten die beiden Vektoren

$$\vec{u} = \begin{pmatrix} 4 \\ u_2 \end{pmatrix}, \qquad \vec{v} = \begin{pmatrix} -1 \\ 1 \end{pmatrix}$$

Wir wissen, dass $\vec{u}$ senkrecht auf $\vec{v}$ steht.
Bestimmen Sie $u_2$:

$u_2 =$ $\boxed{\phantom{0000}}$

***Lösung:***

$u_2 =$ $\boxed{4}$

***Aufgabenname:*** *lal_vek_gen_113*

**Aufgabe 16.4.** Von dem Vektor

$$\vec{u} = \begin{pmatrix} u_1 \\ u_2 \end{pmatrix}$$

wissen wir, dass seine Pfeilspitze auf der Geraden $G$ durch die Punkte $P = (1,\,2)$ und $Q = (2,\,3)$ liegt (d.h. $(u_1, u_2) \in G$).
Bestimmen Sie $u_2$, wenn $u_1 = 6$:

$u_2 =$ $\boxed{\phantom{0000}}$

***Lösung:***

$u_2 =$ $\boxed{7}$

# 17 Grenzwerte und Stetigkeit II

***Aufgabenname:*** *gre_ste_gen_104*

**Aufgabe 17.1.** Wir betrachten die Funktion $y = f(x)$, die durch die folgende Vorschrift definiert ist:

$$f(x) = \begin{cases} x^2 - x + 2 & \text{für } x \geq 1 \\ 3 - x & \text{für } 0 \leq x < 1 \\ (x-2)^2 - 1 & \text{für } x < 0 \end{cases}$$

Dann gilt:

- ☐ Die Funktion ist überall stetig.
- ☐ Die Funktion hat eine Unstetigkeitsstelle in $a = 0$ und ist stetig in $b = 1$.
- ☐ Die Funktion ist stetig in $a = 0$ und hat eine Unstetigkeitsstelle in $b = 1$.
- ☐ Die Funktion hat Unstetigkeitsstellen in $a = 0$ und $b = 1$.

***Lösung:***

- ☑ *Die Funktion ist überall stetig.*

***Aufgabenname:*** *gre_ste_gen_105*

**Aufgabe 17.2.** Wir betrachten die Funktion $y = f(x)$, die durch die folgende Vorschrift definiert ist:

$$f(x) = \begin{cases} x^2 + 2x - 1 & \text{für } x \geq 1 \\ (-x)^2 - x + 4 & \text{für } -1 \leq x < 1 \\ x^2 + x + 4 & \text{für } x < -1 \end{cases}$$

Dann gilt:

- ☐ Die Funktion ist überall stetig.
- ☐ Die Funktion hat eine Unstetigkeitsstelle in $a = -1$ und ist stetig in $b = 1$.

☐ Die Funktion ist stetig in $a = -1$ und hat eine Unstetigkeitsstelle in $b = 1$.

☐ Die Funktion hat Unstetigkeitsstellen in $a = -1$ und $b = 1$.

***Lösung:***

☑ *Die Funktion hat Unstetigkeitsstellen in* $a = -1$ *und* $b = 1$.

***Aufgabenname:*** *gre_ste_gen_106*

**Aufgabe 17.3.** Wir betrachten die Funktion $y = f(x)$, die durch die folgende Vorschrift definiert ist:

$$f(x) = \begin{cases} x+1 & \text{für } x \geq 1 \\ 3 - ax^2 & \text{für } x < 1 \end{cases}$$

Wie muss $a$ gewählt werden, damit daraus eine auf ganz $\mathbb{R}$ stetige Funktion wird?

$a =$ ☐

***Lösung:***

$a =$ $\boxed{1}$

***Aufgabenname:*** *gre_fol_gen_118*

**Aufgabe 17.4.** Bestimmen Sie den Grenzwert, falls dieser existieren. Falls der Grenzwert nicht existiert, schreiben Sie '-' in das entsprechende Feld. (Schreiben Sie alle Zahlen als Dezimalzahlen und runden Sie auf zwei Stellen nach dem Komma, falls Sie keinen exakten Wert erhalten):

$\lim\limits_{t\to\infty} \dfrac{t+t^4}{1-t^4} =$

☐

***Lösung:*** $\lim\limits_{t\to\infty} \dfrac{t+t^4}{1-t^4} =$

$\boxed{-1}$

*Aufgabenname: gre_fol_gen_119*

**Aufgabe 17.5.** Bestimmen Sie den Grenzwert, falls dieser existieren. Falls der Grenzwert nicht existiert, schreiben Sie '-' in das entsprechende Feld. (Schreiben Sie alle Zahlen als Dezimalzahlen und runden Sie auf zwei Stellen nach dem Komma, falls Sie keinen exakten Wert erhalten):

$$\lim_{t\to 0} \frac{t^3 + t^4}{t^3} =$$

**Lösung:** $\lim_{t\to 0} \frac{t^3 + t^4}{t^3} =$

$\boxed{1}$

*Aufgabenname: gre_fol_gen_120*

**Aufgabe 17.6.** Bestimmen Sie den Grenzwert, falls dieser existieren. Falls der Grenzwert nicht exisitiert, schreiben Sie '-' in das entsprechende Feld. (Schreiben Sie alle Zahlen als Dezimalzahlen und runden Sie auf zwei Stellen nach dem Komma, falls Sie keinen exakten Wert erhalten):

$$\lim_{t\to 0} t^2 \cdot \cos\left(\frac{1}{t^2}\right) =$$

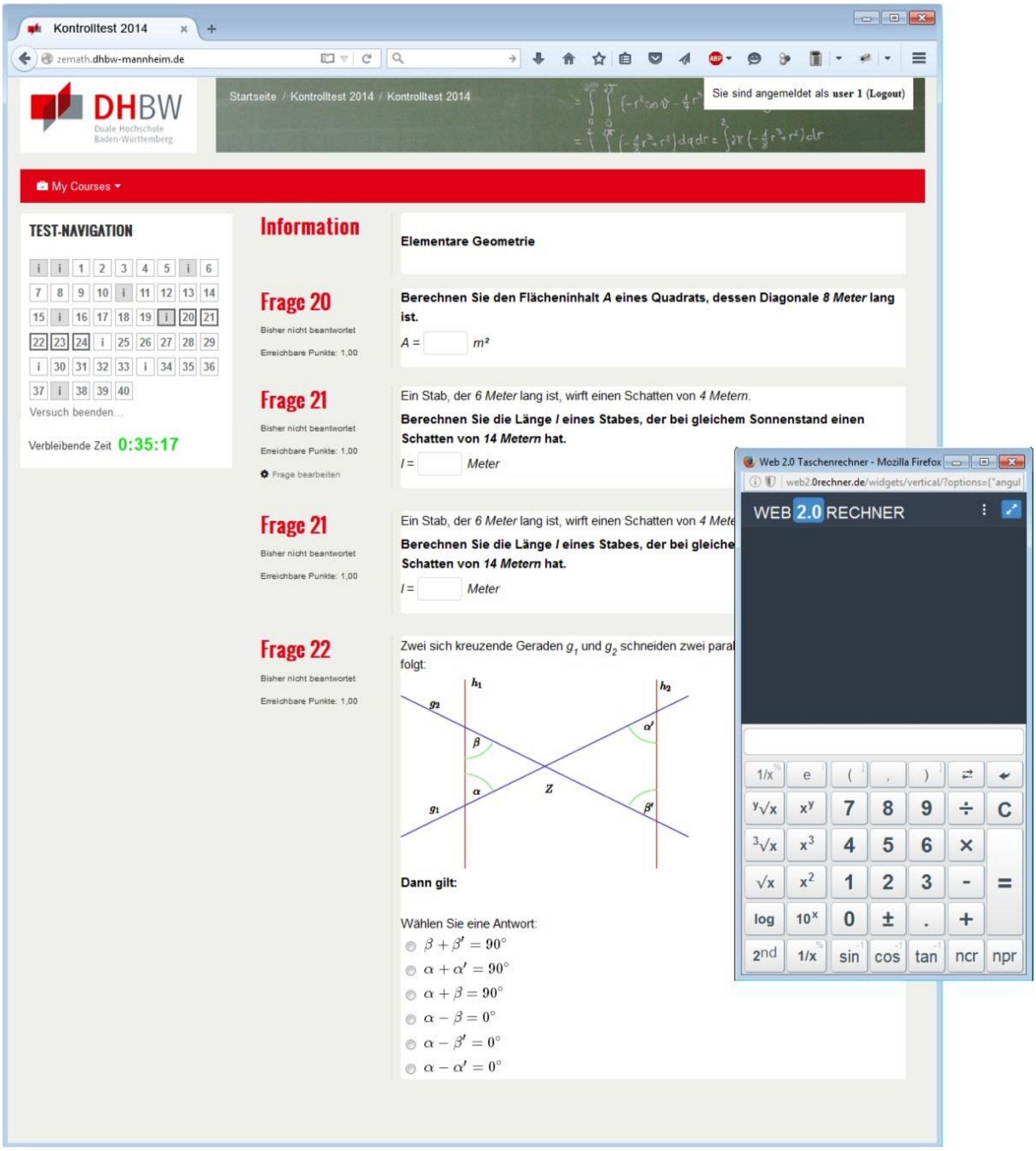
**Lösung:** $\lim_{t\to 0} t^2 \cdot \cos\left(\frac{1}{t^2}\right) =$

$\boxed{0}$

## C.2 Post-test items

40 post-test items, final version of 2014

*Note:* this is the printed / pdf version of the e-elearning quiz. For the original layout see screenshot below (post-test 2014, geometry, questions 20-22, pop-up calculator).



# 1 Arithmetik

*Aufgabenname: ari_ter_kla_103*

**Aufgabe 1.1.** Berechnen Sie den folgenden Ausdruck oder vereinfachen Sie ihn durch Ausklammern, Ausmultiplizieren und Kürzen soweit wie möglich:

$$t = (x - (y - z)) - (y - (z - x))$$

- ☐ $t = 2x - 2y$
- ☐ $t = 2x - 2z$
- ☐ $t = 2z - 2y$
- ☐ $t = -2z$
- ☐ $t = 2x - 2y + 2z$
- ☐ $t = 0$

***Lösung:*** $t = 2z - 2y$

*Aufgabenname: ari_ter_bin_101*

**Aufgabe 1.2.** Berechnen Sie den folgenden Ausdruck oder vereinfachen Sie ihn durch Ausklammern, Ausmultiplizieren und Kürzen soweit wie möglich:

$$t = \frac{x^2 - 2x + 1}{x^2 - 1}$$

- ☐ $t = \frac{1}{x+1}$
- ☐ $t = \frac{x+1}{x-1}$
- ☐ $t = \frac{x-1}{x+1}$
- ☐ $t = \frac{x-2}{x}$
- ☐ $t = -2x + 2$

- ☐ Der Ausdruck kann nicht vereinfacht werden, $t = \dfrac{x^2 - 2x + 1}{x^2 - 1}$.

***Lösung:*** $t = \dfrac{x-1}{x+1}$

***Aufgabenname:*** *ari_bru_gen_109*

**Aufgabe 1.3.** Berechnen Sie den folgenden Ausdruck oder vereinfachen Sie ihn durch Ausklammern, Ausmultiplizieren und Kürzen soweit wie möglich:

$t = \dfrac{1}{\dfrac{1}{x} - \dfrac{1}{y}}$.

- ☐ $t = \dfrac{yx}{y-x}$
- ☐ $t = \dfrac{xy}{x-y}$
- ☐ $t = \dfrac{y-x}{yx}$
- ☐ $t = \dfrac{x-y}{xy}$
- ☐ $t = x - y$
- ☐ Der Ausdruck kann nicht vereinfacht werden, $t = \dfrac{1}{\dfrac{1}{x} - \dfrac{1}{y}}$.

***Lösungsweg/Erklärung:*** *Es ist*

$$\frac{1}{\frac{1}{x} - \frac{1}{y}} = \frac{1}{\frac{y-x}{xy}} = \frac{xy}{y-x} = \frac{yx}{y-x}$$

***Lösung:***

- ☑ $t = \dfrac{yx}{y-x}$
- ☐ $t = \dfrac{xy}{x-y}$
- ☐ $t = \dfrac{y-x}{yx}$

- ☐ $t = \dfrac{x-y}{xy}$
- ☐ $t = x - y$
- ☐ *Der Ausdruck kann nicht vereinfacht werden,* $t = \dfrac{1}{\frac{1}{x} - \frac{1}{y}}$.

***Aufgabenname:*** *ari_pro_gen_101*

**Aufgabe 1.4.** Ein Elektronikfachgeschäft schlägt auf den Einkaufspreis eines Mobiltelefons 40% auf und verkauft das Gerät für 350,00 €.
Wie hoch ist der Einkaufspreis?

***Lösung:*** *250,00 €*

***Aufgabenname:*** *ari_ter_bin_110*

**Aufgabe 1.5.** Welche positive Zahl $a$ erfüllt die Gleichung

$$(a+3)(a-3) = 7$$

- ☐ $a = 1$.
- ☐ $a = 2$.
- ☐ $a = 3$.
- ☐ $a = 4$.
- ☐ $a = 5$.
- ☐ Keiner der angegebenen Werte für $a$ ist eine Lösung.

***Lösungsweg/Erklärung:*** *Es ist*

$$(a+3)(a-3) = a^2 - 9$$

*nach der dritten binomischen Formel. Zu lösen ist also die Gleichung*

$$a^2 - 9 = 7$$

*oder äquivalent*

$$a^2 = 16$$

*Diese hat die beiden Lösungen $a_1 = -4$ und $a_2 = 4$. Nur $a_2$ ist positiv und in der Liste enthalten.*

***Lösung:***

- ☐ $a = 1$.
- ☐ $a = 2$.
- ☐ $a = 3$.
- ☑ $a = 4$.
- ☐ $a = 5$.
- ☐ *Keiner der angegebenen Werte für $a$ ist eine Lösung.*

# 2 Gleichungen

***Aufgabenname:*** *gle_lin_gen_101*

**Aufgabe 2.1.** Ein Internetprovider bietet zwei Movie–Tarife an, einen Tarif *Standard* mit einer Grundgebühr von 10 € pro Monat, der 3 kostenlose Downloads beinhaltet und bei dem jeder weitere Film 1,80 € kostet, und einen Tarif *Deluxe*, der 25 € pro Monat kostet und unbegrenzt viele Downloads erlaubt.
Wie viele Filme müssen Sie im Monat mindestens beziehen, damit der Tarif *Deluxe* für Sie günstiger ist?

***Lösung:*** *12 Filme*

***Aufgabenname:*** *gle_lin_gen_102*

**Aufgabe 2.2.** Ein Bauer hat Hühner, Enten und Gänse auf seinem Hof. Dabei hat er doppelt so viele Enten wie Gänse und doppelt so viele Hühner wie Enten. Insgesamt hat er 210 Tiere.

Wie viele Gänse befinden sich auf dem Hof?

***Lösung:*** *30 Gänse*

***Aufgabenname:*** *gle_lin_gen_103*

**Aufgabe 2.3.** Das Produkt zweier positiver ganzer Zahlen, deren Differenz 4 beträgt, ist 96.
Wie lautet die kleinere der beiden Zahlen?

***Lösung:*** *8*

***Aufgabenname:*** *gle_lin_gen_104*

**Aufgabe 2.4.** Zwei Zahlen $x, y$ erfüllen

$$x + y = x^2 - y^2$$
$$x + y = 25$$

Dann gilt:

- ☐ $x = 1$
- ☐ $x = 12$
- ☐ $x = 13$
- ☐ $x = 26$
- ☐ $x = 25$
- ☐ $x = 52$

***Lösung:***

- ☑ $x = 13$

***Aufgabenname:*** *gle_ung_gen_101*

**Aufgabe 2.5.** Die Lösungsmenge $L$ der Ungleichung

$$-2x^2 + 6x \geq 0$$

ist

- ☐ $L = ]-\infty,\, 3]$
- ☐ $L = [3,\, \infty[$
- ☐ $L = [0,\, 3]$
- ☐ $L = ]0,\, 3[$
- ☐ $L = [-3,\, 3]$
- ☐ $L = ]-\infty,\, -3] \cup [3,\, \infty[$

***Lösung:***

- ☑ $L = [0,\, 3]$

# 3 Potenzen, Wurzeln, Logarithmen

***Aufgabenname:*** *pwl_pot_gen_101*

**Aufgabe 3.1.** Berechnen Sie $t = 3 \cdot \left(2^2\right)^3 - 4 \cdot 2^2 \cdot 2^3 - 2^3 \cdot (5 + 2^{-1})$

***Lösung:*** $t = 20$

***Aufgabenname:*** *pwl_wur_gen_101*

**Aufgabe 3.2.** Vereinfachen Sie $t = \dfrac{\sqrt{5^6 \cdot (-2)^4}}{\sqrt[3]{5^6 \cdot 2^6}}$.

- ☐ $t = 5$
- ☐ $t = \frac{1}{2}$
- ☐ $t = -\frac{5}{2}$
- ☐ $t = \frac{5}{2}$
- ☐ $t = \frac{\sqrt{5}}{\sqrt[3]{2}}$
- ☐ Der Ausdruck kann nicht vereinfacht werden, $t = \frac{\sqrt{5^6 \cdot (-2)^4}}{\sqrt[3]{5^6 \cdot 2^6}}$

**Lösung:**

- ☑ $t = 5$

**Aufgabenname:** *pwl_wur_gen_102*

**Aufgabe 3.3.** Ein quaderförmiger Steinblock ist doppelt so tief wie breit und dreimal so hoch wie breit. Er hat ein Volumen von $1296\,m^3$.
Wie breit ist der Steinblock?

**Lösung:** *6 Meter*

**Aufgabenname:** *pwl_log_gen_101*

**Aufgabe 3.4.** Berechnen Sie den folgenden Ausdruck oder vereinfachen Sie ihn durch Ausklammern, Ausmultiplizieren und Kürzen soweit wie möglich:

$$t = \ln\left(\frac{e^{3x}}{e^{5x}}\right) + e^{\ln(3)+\ln(x)}$$

- ☐ $t = x$
- ☐ $t = \frac{18}{5} + x$
- ☐ $t = 3^x - 2x$
- ☐ $t = 3 - x$
- ☐ $t = \frac{3}{5} + 3x$
- ☐ Der Ausdruck kann nicht vereinfacht werden, $t = \ln\left(\frac{e^{3x}}{e^{5x}}\right) + e^{\ln(3)+\ln(x)}$.

**Lösung:** $t = x$

**Aufgabenname:** *pwl_log_gen_102*

**Aufgabe 3.5.** Was ist $\log_{100}(1000)$?

**Lösung:** $1,5$

# 4 Funktionen

***Aufgabenname:*** *fun_lin_gen_110*

**Aufgabe 4.1.** Der Graph der lineare Funktion $f$ schneidet die $y$–Achse an der Stelle $4$ und geht durch den Punkt $(3, 3)$. Bestimmen Sie die Stelle, an der der Graph die $x$–Achse schneidet.

$x = \boxed{\phantom{12}}$

***Lösungsweg/Erklärung:*** *Die Funktion geht durch die beiden Punkte* $(0, 4)$ *und* $(3, 3)$*, hat also die Steigung* $m = \frac{3-4}{3-0} = -\frac{1}{3}$*. Da der* $y$*–Achsenabschnitt den Wert* $4$ *hat, wird* $f$ *durch die Gleichung*

$$f(x) = -\frac{1}{3}x + 4$$

*beschrieben, und die zugehörige Gleichung*

$$-\frac{1}{3}x + 4 = 0$$

*hat die Lösung* $x = 12$*.*

***Lösung:***

$x = \boxed{12}$

***Aufgabenname:*** *fun_qua_gen_104*

**Aufgabe 4.2.** Die Funktion $y = x^2 + bx + c$ beschreibt eine nach oben geöffnete Normalparabel mit Scheitel im Punkt $(-1, 1)$.
Bestimmen Sie $b$ und $c$.

***Lösung:***

$$b = \boxed{2}$$
$$c = \boxed{2}$$

***Aufgabenname:*** *fun_qua_gen_105*

**Aufgabe 4.3.** Eine Kugel wird senkrecht nach oben geworfen. Ihre Höhe $h$ (in Metern) zum Zeitpunkt $t$ (in Sekunden) berechnet sich nach der Formel

$$h = 30t - 3t^2$$

Was ist die höchste Höhe, die erreicht wird, und nach wie viel Sekunden wird sie erreicht?

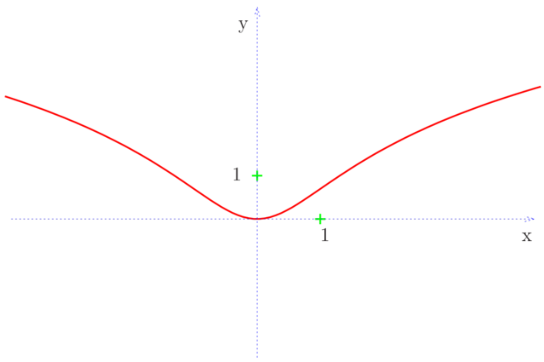
***Lösung:***

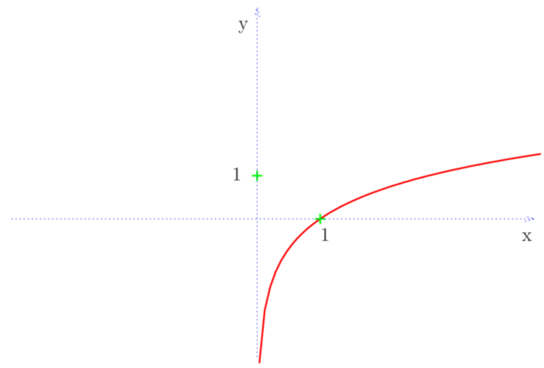
$h_{max} = \boxed{75}$ $\qquad$ $t_{max} = \boxed{5}$

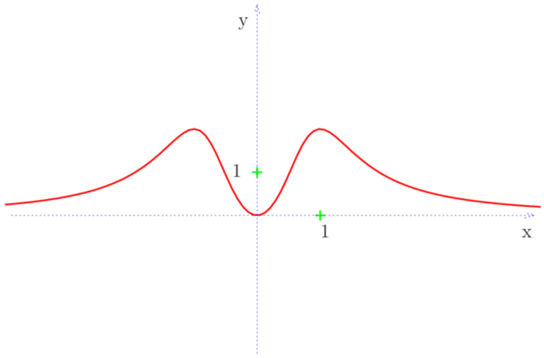
***Aufgabenname:*** *fun_log_gen_101*

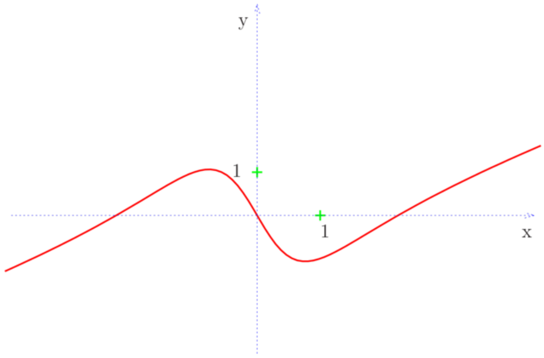
**Aufgabe 4.4.** Welches der folgenden Bilder beschreibt den Graphen der Funktion

$$y = \ln(x^2 + 1)$$






***Lösung:*** *Graph 1*

# 5 Geometrie

***Aufgabenname:*** *geo_fla_pyt_101*

**Aufgabe 5.1.** Berechnen Sie den Flächeninhalt $A$ eines Quadrats, dessen Diagonale $8\,m$ lang ist.

***Lösung:*** $32m^2$

***Aufgabenname:*** *geo_str_gen_108*

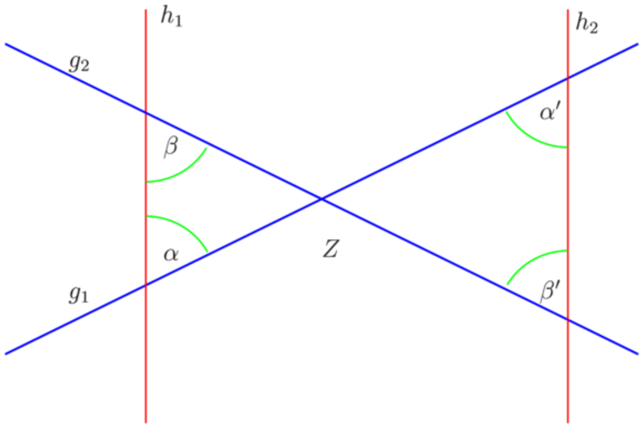
**Aufgabe 5.2.** Ein Stab, der 6 Meter lang ist, wirft einen Schatten von 4 Metern.

Berechnen Sie die Länge $l$ eines Stabs, der bei gleichem Sonnenstand einen Schatten von 14 Metern hat?

***Lösung:*** $l = 21m$

***Aufgabenname:*** *geo_str_gen_109*

**Aufgabe 5.3.** Zwei sich kreuzende Geraden $g_1$ und $g_2$ schneiden zwei parallele Geraden $h_1$ und $h_2$ wie folgt




Dann gilt

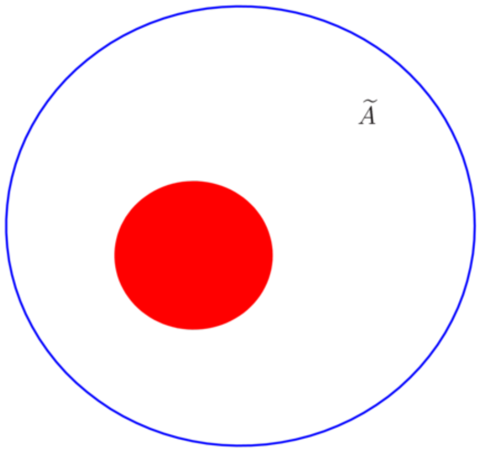
- ☐ $\alpha + \beta = 90°$.
- ☐ $\alpha + \alpha' = 90°$.
- ☐ $\beta + \beta' = 90°$.
- ☐ $\alpha - \beta = 0°$.
- ☐ $\alpha - \alpha' = 0°$.
- ☐ $\alpha - \beta' = 0°$.

***Lösung:***

☑ $\alpha - \alpha' = 0°$.

*Aufgabenname:* *geo_kre_gen_105*

**Aufgabe 5.4.** Aus einer Kreisscheibe mit Radius $R$ und Fläche $A$ wird eine kleinere (rote) Kreisscheibe mit Radius $r = \frac{R}{3}$ wie folgt herausgeschnitten




Dann gilt für die Fläche $\widetilde{A}$ des verbleibenden Kreisrings:

☐ $\widetilde{A} = \frac{1}{3}A$.

☐ $\widetilde{A} = \frac{2}{3}A$.

☐ $\widetilde{A} = \frac{1}{9}A$.

☐ $\widetilde{A} = \frac{8}{9}A$.

☐ $\widetilde{A} = \frac{3}{4}A$.

☐ $\widetilde{A} = \frac{5}{6}A$.

***Lösung:***

☑ $\widetilde{A} = \frac{8}{9}A$.

*Aufgabenname:* *geo_ste_qua_102*

**Aufgabe 5.5.** Eine Pyramide mit quadratischer Grundfläche mit Seitenlänge $a$ hat ein Gewicht von 2 Tonnen.
Wie schwer ist eine Pyramide mit gleicher Höhe und quadratischem Grundriss der Seitenlänge $2a$?

***Lösung:*** $8t$

# 6 Trigonometrie

***Aufgabenname:*** *tri_fun_gen_101*

**Aufgabe 6.1.** Vom Winkel $\alpha$ wissen wir, dass $\sin(\alpha) < 0$ und $\cos(\alpha) > 0$. Dann gilt

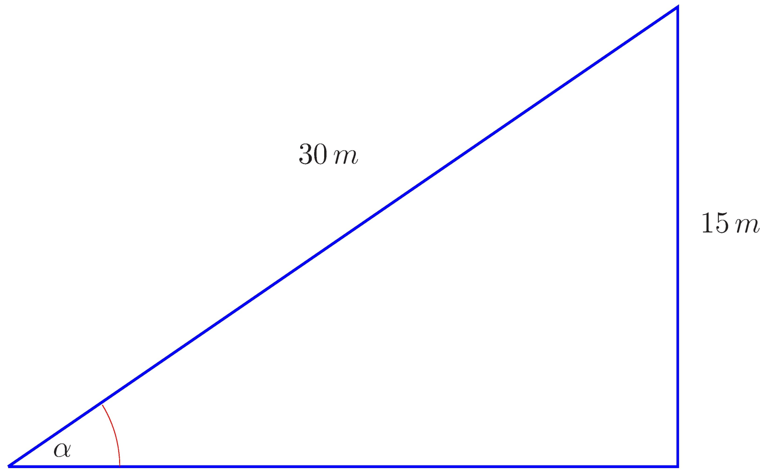
- ☐ $0° < \alpha < 90°$.
- ☐ $90° < \alpha < 180°$.
- ☐ $180° < \alpha < 270°$.
- ☐ $270° < \alpha < 360°$.
- ☐ Es kann nichts über die Größenordnung von $\alpha$ gesagt werden.

***Lösung:***

- ☑ $270° < \alpha < 360°$.

***Aufgabenname:*** *tri_ark_fun_104*

**Aufgabe 6.2.** Ein Frosch sieht die Spitze eines senkrecht eingeschlagenen, $15\,m$ hohen Pfahls in einer Entfernung von $30\,m$. Unter welchem Winkel (vom Boden aus gemessen) sieht der Frosch die Pfahlspitze?




Geben Sie den Winkel $\alpha$ im Gradmaß an.

$\alpha = \boxed{\quad\quad ^\circ}$

***Lösungsweg/Erklärung:*** *Der Pfahl der Länge $p = 15\,m$ und die Verbindungslinie von Frosch zu Pfahlspitze der Länge $l = 30\,m$ bilden Gegenkathete und Hypotenuse eines rechtwinkligen Dreiecks mit dem Winkel $\alpha$. Daher gilt nach Definition*

$$\sin(\alpha) = \frac{p}{l} = \frac{1}{2}$$

*und damit ist*

$$\alpha = \arcsin\left(\frac{1}{2}\right) = 30^\circ$$

***Lösung:***

$\alpha = \boxed{30^\circ}$

***Aufgabenname:*** *tri_gle_gen_104*

**Aufgabe 6.3.** Für welche Zahlen $x \in [0, 2\pi]$ gilt

$$\sin\left(x + \frac{\pi}{3}\right) = 0$$

- ☐ $x = \frac{\pi}{3}$.
- ☐ $x = \frac{2\pi}{3}$.
- ☐ $x = \frac{\pi}{3}$ und $x = \frac{4\pi}{3}$.
- ☐ $x = \pi$.
- ☐ $x = \frac{2\pi}{3}$ und $x = \frac{5\pi}{3}$.
- ☐ $x = \frac{\pi}{2}$ und $x = \frac{3\pi}{2}$.

***Lösungsweg/Erklärung:*** *Es ist $\sin(y) = 0$ genau dann, wenn $y = k\pi$ für ein $k \in \mathbb{Z}$. Also muss gelten*

$$x + \frac{\pi}{3} = k\pi$$

*für ein $k \in \mathbb{Z}$. Mit der Einschränkung $x \in [0, 2\pi]$ ergeben sich die beiden Lösungen*

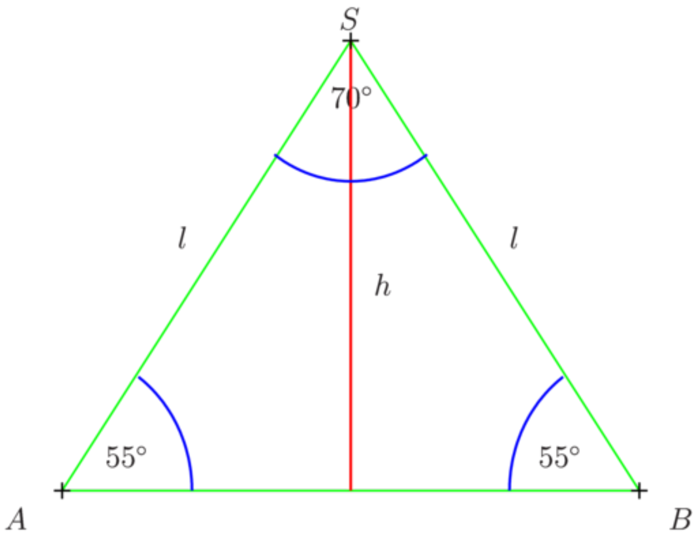
$$x = \frac{2\pi}{3} \quad \text{und } x = \frac{5\pi}{3}$$

***Lösung:***

- ☐ $x = \frac{\pi}{3}$.
- ☐ $x = \frac{2\pi}{3}$.
- ☐ $x = \frac{\pi}{3}$ *und* $x = \frac{4\pi}{3}$.
- ☐ $x = \pi$.
- ☑ $x = \frac{2\pi}{3}$ *und* $x = \frac{5\pi}{3}$.
- ☐ $x = \frac{\pi}{2}$ *und* $x = \frac{3\pi}{2}$.

***Aufgabenname:*** *tri_fun_gen_102*

**Aufgabe 6.4.** Eine Sprossen–Doppelleiter mit einfacher Leiterlänge $l = 1{,}5\,m$ wird so aufgestellt, dass die Seiten der Leiter einen Winkel von $70°$ bilden,




Nach welcher Formel berechnet sich die Höhe $h$ der aufgestellten Leiter?

- ☐ $h = l \cdot \tan(35°)$.
- ☐ $h = l \cdot \sin(35°)$.
- ☐ $h = l \cdot \cos(35°)$.
- ☐ $h = l \cdot \sin(70°)$.
- ☐ $h = l \cdot \cot(55°)$.
- ☐ $h = l \cdot \cos(70°)$.

***Lösung:***

- ☑ $h = l \cdot \cos(35°)$.

***Aufgabenname:*** *tri_fun_gen_103*

**Aufgabe 6.5.** Bei einem Sonnenstand von $30°$ zum Horizont wirft ein Baum einen Schatten von $26\,m$.

Wie hoch ist der Baum (gerundet auf ganze Meter)?

***Lösung:*** $15m$

# 7 Logik und Kombinatorik

***Aufgabenname:*** *log_kom_gen_101*

**Aufgabe 7.1.** Wie groß ist die Wahrscheinlichkeit $p$, bei zwei Würfen mit einem (ungezinkten) Würfel nie eine "6" zu würfeln?

- ☐ $p = \frac{1}{6}$
- ☐ $p = \frac{1}{36}$
- ☐ $p = \frac{35}{36}$
- ☐ $p = \frac{25}{36}$
- ☐ $p = \frac{11}{36}$
- ☐ $p = \frac{2}{36}$

***Lösung:***

- ☑ $p = \frac{25}{36}$

***Aufgabenname:*** *log_kom_gen_102*

**Aufgabe 7.2.** In einem Topf befinden sich sieben Zettel mit den Ziffern $1, \ldots, 7$. Anna zieht zwei Zettel und legt sie in der Reihenfolge, in der sie sie zieht, aneinander.
Wie viele zweistellige Zahlen kann Sie auf diese Art und Weise bekommen?

***Lösung:*** 42

***Aufgabenname:*** *log_wah_gen_101*

**Aufgabe 7.3.** Auf einer Insel leben nur Ritter und Knappen. Ritter sagen stets die Wahrheit, Knappen lügen immer. August und Berthold sind Bewohner der Insel. August sagt: "Wir beide sind Knappen." Dann gilt

- ☐ August und Berthold sind Knappen.
- ☐ August und Berthold sind Ritter.
- ☐ August ist Ritter und Berthold ist Knappe.
- ☐ August ist Knappe und Berthold ist Ritter.
- ☐ Die Aussage von August lässt keine eindeutige Schlussfolgerung zu.

***Lösung:***

- ☑ *August ist Knappe und Berthold ist Ritter.*

***Aufgabenname:*** *log_sch_gen_101*

**Aufgabe 7.4.** In der folgenden "Beweisführung" ist genau eine Schlussfolgerung falsch. Welche?

$$\begin{aligned} 2 < 3 &\overset{(1)}{\Longrightarrow} 3 < 4 \\ &\overset{(2)}{\Longrightarrow} 2^3 < 2^4 \\ &\overset{(3)}{\Longrightarrow} \frac{1}{2^3} < \frac{1}{2^4} \\ &\overset{(4)}{\Longrightarrow} 2 < 1 \\ &\overset{(5)}{\Longrightarrow} 3 < 2 \end{aligned}$$

Falsch ist

- ☐ Schritt (1)

- ☐ Schritt (2)
- ☐ Schritt (3)
- ☐ Schritt (4)
- ☐ Schritt (5)

***Lösung:***

- ☑ *Schritt (3)*

# 8 Vektorrechnung

***Aufgabenname:*** *lal_ana_gen_103*

**Aufgabe 8.1.** Welcher Punkt $T$ teilt die Verbindungsstrecke zwischen den beiden Punkten $P = (3,\ 4,\ 1)$ und $Q = (9,\ 1,\ 10)$ im Verhältnis 1:2 ?

- ☐ $T = (5,\ 3,\ 4)$.
- ☐ $T = (7,\ 2,\ 7)$.
- ☐ $T = (2,\ -1,\ 3)$.
- ☐ $T = (4,\ -2,\ 6)$.
- ☐ $T = (4,\ 3,\ 5)$.
- ☐ $T = (1,\ 2,\ 3)$.

***Lösung:***

- ☑ $T = (5,\ 3,\ 4)$.

***Aufgabenname:*** *lal_ana_gen_104*

**Aufgabe 8.2.** Der Verbindungsvektor der Punkte $P$ und $Q$ hat die Koordinatendarstellung

$$\overrightarrow{PQ} = \begin{pmatrix} 5 \\ 3 \\ 4 \end{pmatrix}$$

und es ist $Q = (4,\ 4,\ -4)$. Dann gilt

- ☐ $P = (1,\ -1,\ 8)$.
- ☐ $P = (-1,\ 1,\ -8)$.
- ☐ $P = (9,\ 7,\ 0)$.
- ☐ $P = (1,\ -1,\ 0)$.
- ☐ $P = (1,\ 2,\ 3)$.

***Lösung:***

- ☑ $P = (-1,\ 1,\ -8)$.

***Aufgabenname:*** *lal_ana_abs_pug_101*

**Aufgabe 8.3.** Berechnen Sie den Abstand $d$ des Punktes $P = (\sqrt{2}, \sqrt{2})$ von der Geraden $G$ durch die Punkte $A = (1,\ -1)$ und $B = (-1,\ 1)$.

***Lösung:*** $d = 2$

***Aufgabenname:*** *lal_gls_gen_101*

**Aufgabe 8.4.** Beim Hammerwerfen der Männer wiegt ein Wurfhammer $7\,kg$, bei den Frauen wiegt der Wurfhammer $4\,kg$.

Wie viele Wurfhämmer für Frauen befinden sich in einer Kiste, wenn die Kiste 15 Wurfhämmer enthält und ihr Inhalt $84\,kg$ wiegt?

***Lösung:*** 7

# 9 Grenzwerte und Stetigkeit

*Aufgabenname: gre_fol_gen_101*

**Aufgabe 9.1.** Bestimmen Sie den folgenden Grenzwert, falls er existiert. Falls der Grenzwert nicht existiert, schreiben Sie '-' in das entsprechende Feld:

$$\lim_{t\to\infty} \frac{1+2t^2}{2+t^2} = \boxed{\phantom{0}}$$

***Lösung:*** $\lim_{t\to\infty} \frac{1+2t^2}{2+t^2} = \boxed{2}$

*Aufgabenname: gre_fol_gen_103*

**Aufgabe 9.2.** Bestimmen Sie den folgenden Grenzwert, falls er existiert. Falls der Grenzwert nicht existiert, schreiben Sie '-' in das entsprechende Feld:

$$\lim_{n\to\infty} \frac{4n^3+3n^2+5n+9}{2n^4+4n^2+2} = \boxed{\phantom{0}}$$

***Lösung:*** $\lim_{n\to\infty} \frac{4n^3+3n^2+5n+9}{2n^4+4n^2+2} = \boxed{0}$

*Aufgabenname: gre_ste_gen_101*

**Aufgabe 9.3.** Wir betrachten die Funktion $y = f(x)$, die durch die folgende Vorschrift definiert ist:

$$f(x) = \begin{cases} x^2 - x + 2 & \text{für } x \geq 2 \\ \frac{x+2}{2} & \text{für } 0 \leq x < 2 \\ (x+1)^2 + 1 & \text{für } x < 0 \end{cases}$$

Dann gilt:

- ☐ Die Funktion ist überall stetig.
- ☐ Die Funktion hat eine Unstetigkeitsstelle in $a = 0$ und ist stetig in $b = 2$.
- ☐ Die Funktion ist stetig in $a = 0$ und hat eine Unstetigkeitsstelle in $b = 2$.
- ☐ Die Funktion hat Unstetigkeitsstellen in $a = 0$ und $b = 2$.

***Lösung:***

- ☑ *Die Funktion hat Unstetigkeitsstellen in $a = 0$ und $b = 2$.*

# D Surveys

## D.1 Demographic and personal variables

The following nine questions were presented to participants before being forwarded to the diagnostic pretest.

*Note:* In 2013 the answers were routinely compared to those collected by the university's administration. The item referring to a student's type of secondary school graduation showed inconsistent results: a considerable number of students (89 out of 725) had chosen the wrong type of graduation from the drop-down list; the administrative files were found to be correct. Either these students had been unsure about the type of graduation they had achieved or they did not take the issue very seriously. In the face of the relatively high number of inconsistent answers (12% of that year's sample) the type-of-graduation variable was re-coded for all cohorts based on the university's administrative data. The university's database was also used to collect students' grades in their final school certificate.

**1 Year of birth:** (numeric entry)

**2 gender:** male / female (radio button)

**3 Type of secondary school degree** (drop-down menu)

a) Allgemeine Hochschulreife / Abitur: Gymnasium

b) Allgemeine Hochschulreife / Abitur: Berufliches Gymnasium (Fachgymnasium)

c) Allgemeine Hochschulreife / Abitur: Beruflich Qualifiziert (Meisterabitur)

d) Allgemeine Hochschulreife / Abitur: sonstige

e) Fachhochschulreife: Berufsfachschule

f) Fachhochschulreife: Fachoberschule

g) Fachhochschulreife: other

h) other

**4 If 3. a): Eight- or nine-years of Gymnasium?**

eight / nine years (radio button)

**5 If 3. b) or other:**

technical focus / economic focus / other (radio button)

**6 Year of graduation from secondary school** (numeric entry)

**7 Secondary school was in…** (drop-down menu)

1. Baden-Württemberg
2. Bayern
3. Berlin
4. Brandenburg
5. Bremen
6. Hamburg
7. Hessen
8. Mecklenburg-Vorpommern
9. Niedersachsen
10. Nordrhein-Westfalen
11. Rheinland-Pfalz
12. Saarland
13. Sachsen
14. Sachsen-Anhalt
15. Schleswig-Holstein
16. Thüringen
17. EU
18. other

**8 How did you usually perform in school mathematics during the last three years of secondary school?** (radio button)

1. not too good (D and lower)
2. average (B/C)
3. good (A/B)
4. very good (A*/A)
5. I got (nearly) all grades from A to G

**9 How do you recall mathematics as a school subject?** (radio button)

1. problem area
2. necessary evil
3. ok
4. often had fun
5. my favourite subject
6. other

## D.2 Self-reports on mathematical areas

The following questions were added to the demographic and personal item set in 2012. They were only used for that cohort.

**Now we would like you to reflect on your school knowledge. Please have a look at the listed mathematical areas: Are these expressions common to you? And if, how would you estimate your knowledge in these areas?** (radio buttons)

**10 Arithmetic**

I think I have a good fundamental knowledge in this area
I am not sure about my knowledge in this area
I am afraid I might have some gaps in this area
other

**11 Equations**

I think I have a good fundamental knowledge in this area
I am not sure about my knowledge in this area
I am afraid I might have some gaps in this area
other

**12 Powers, roots, logarithms**

I think I have a good fundamental knowledge in this area
I am not sure about my knowledge in this area
I am afraid I might have some gaps in this area
other

**13 Functions**

I think I have a good fundamental knowledge in this area
I am not sure about my knowledge in this area
I am afraid I might have some gaps in this area
other

**14 Geometry**

I think I have a good fundamental knowledge in this area
I am not sure about my knowledge in this area
I am afraid I might have some gaps in this area
other

**15 Trigonometry**

I think I have a good fundamental knowledge in this area
I am not sure about my knowledge in this area

I am afraid I might have some gaps in this area

This subject was not taught at school

I never heard of this expression

other

**16 Logic**

I think I have a good fundamental knowledge in this area

I am not sure about my knowledge in this area

I am afraid I might have some gaps in this area

This subject was not taught at school

I never heard of this expression

other

**17 Vectors and linear algebra**

I think I have a good fundamental knowledge in this area

I am not sure about my knowledge in this area

I am afraid I might have some gaps in this area

This subject was not taught at school

I never heard of this expression

other

**18 Continuous functions**

I think I have a good fundamental knowledge in this area

I am not sure about my knowledge in this area

I am afraid I might have some gaps in this area

This subject was not taught at school

I never heard of this expression

other

**19 Limits**

I think I have a good fundamental knowledge in this area

I am not sure about my knowledge in this area

I am afraid I might have some gaps in this area

This subject was not taught at school

I never heard of this expression

other

## D.3 Attitude towards mathematics

### How much do you agree with these statements about mathematics?

(strongly disagree / disagree / neutral / agree / strongly agree)

| | Item | Dimension | source |
|---|---|---|---|
| 1 | *I enjoy learning mathematics* | LM | TIMSS |
| 2 | *I am interested in mathematics* | LM | TIMSS |
| 3 | *I learn things quickly in mathematics* | SCLM | TIMSS |
| 5 | *Mathematics is harder for me than any other subject** | SCLM | TIMSS |
| 6 | *Mathematical proofs are interesting* | LM | TIMSS mod. |
| 7 | *I am good with formulae* | SCLM | TIMSS |
| 8 | *I prefer mathematical exercises that are related to technical applications* | LM | own |
| 9 | *I prefer mathematical exercises that are related to my degree programme* | LM | own |
| 9 | *I feel well prepared for my course of study* | SCLM | own |
| 10 | *I am confident that my knowledge will be sufficient for university* | SCLM | TIMSS |
| 11 | *I look forward to the mathematics lectures at university* | LM | TIMSS mod. |
| 12 | *At school, mathematics was my favourite subject* | LM | TIMSS mod. |

*reverse coded

*Dimensions: LM Liking Mathematics (7 Items), SCLM Self Confidence in Learning Mathematics (5 Items)*

**Interpretation of scales**
LM (liking mathematics) scale:
“strongly agree” (interpretation: participant likes mathematics)
“agree” (interpretation: participant likes mathematics somehow)
“disagree” / “strongly disagree” (interpretation: participant does not like mathematics)

SCLM (self-confidence in learning mathematics) scale:
“strongly agree” (interpretation: participant is self-confident)
“agree” (interpretation: participant is not very self-confident)
“disagree” / “strongly disagree” (interpretation: participant is not self-confident)

## D.4 Evaluation questionnaire

In 2011 and 2012, and 2013 the evaluation questionnaire was presented to participants before being forwarded to the control-test (posttest). In order to take pressure from test participants and (presumably) make questionnaire answers more reliable the evaluation was isolated from the control-test in 2014; students now were invited via e-mail to answer the survey.

The survey presented here is the final version of 2014. In the course of the study the e-learning environment underwent some changes, thus the survey had to be adapted, as well. For example, the revised diagnostic feedback was evaluated since 2013, and a set of questions addressing the e-tutoring course was added in 2014.

**1 Where did you take the entry test?** (radio button)

- at the office, alone
- at the office, in a group of students
- at home
- other (open comment)

**2 How difficult was the entry test in your opinion?**

scale from 1 very easy to 5 very difficult

**3 How would you describe the test's usability?**

scale from 1 very poor to 5 very good

**4 Do you have any remarks, suggestions for improving usability?** (open comment)

**5 Did you experience technical problems (crash, long waiting periods...)?** (radio button)

- many problems
- some problems
- no problems

**6 Description of technical problems** (open comment)

**7 After the entry-test you were provided with a feedback based on mathematical categories. How helpful for your learning were these learning recommendations?**

scale from 1 not helpful to 5 very helpful

**8 Do you have any remarks, suggestions for improving the entry-test feedback?** (open comment)

**9 Did you work through one or more of the e-learning modules?** (radio button)

- ○ yes
- ○ no

if 9 - no:

**10 Would you like to name reasons why you did not make use of the learning material?**

if 9 - yes:

**10 Which of the ten learning modules did you work through?** (multiple answer matrix; choices:1 = Online version , 2 = PDF version, 3 = both, n/a = not applicable)

- ☐ 1 Arithmetic
- ☐ 2 Equations
- ☐ 3 Powers, roots and logarithms
- ☐ 4 Functions
- ☐ 5 Geometry
- ☐ 6 Trigonometry
- ☐ 7 Logic
- ☐ 8 Real numbers
- ☐ 9 Vectors and linear algebra
- ☐ 10 Continuous functions and limits
- ☐ I cannot remember the title of the learning module(s)

**11 How difficult / complex were the learning modules?**

scale from 1 very easy to 5 very difficult

**12 How would you describe the usability of the e-learning environment?**

scale from 1 very poor to 5 very good:

- Navigation

- Clarity

- Input / submission of answers

**13 Do you have any remarks, suggestions for improvement concerning the learning modules?** (open comment)

**14 How much time did you invest in your study preparation (on average per week)?** (radio button)

- Less than five hours
- Five to ten hours
- Ten to fifteen hours
- Fifteen to twenty hours
- More than twenty
- other (open comment)

**15 Based on your experience: Which form of self-study do you prefer?** (radio button)

- Online learning modules
- PDF scripts
- both
- other (open comment)

**16 Considering your experience with the Online learning modules: Are there types of mathematical exercises that you preferred to study with?** (multiple answer)

**I liked mathematical exercises that...**

- ☐ ... show general applications of mathematics (e.g. daily life, interest calculations, ..)
- ☐ ... show technical applications of mathematics (e.g. flight path, breaking distance, ...).
- ☐ ... show engineering applications of mathematics as needed in my study programme (e.g. electric engineering: wave motion; computer science: logic).
- ☐ ... are not related to practical examples but simply demand calculating.
- ☐ ... include a mathematical argument / proof.
- ☐ other (open comment).

**17 Did you participate in the e-tutoring course? (2014 only)** (radio button)

- o yes
- o no

if 17 - yes:

**18 Which elements of the e-tutoring course were particularly helpful for your learning?** (multiple answer)

- ☐ read forum entries
- ☐ post forum entries
- ☐ exercise sheets
- ☐ e-tutor feedback to exercise sheets
- ☐ e-mail communication with e-tutor
- ☐ learning suggestions from e-tutor
- ☐ learning suggestions from peers
- ☐ support from e-tutor regarding learning strategies, motivation, time management
- ☐ other (open comment)

**19 How would you describe the interaction with the e-tutor?**

The tutor ...(scale from 1 do not agree to 5 agree a lot):

- answered questions promptly
- answered questions in a comprehensible way
- gave comprehensible feedback to the exercise sheet
- was able to motivate students

**20 Do you have any remarks, suggestions for improvement concerning the e-tutoring programme?** (open comment)

**21 Did you undertake any additional activities to prepare for university mathematics?** (multiple answer)

☐ school books
☐ Internet sites on mathematics (e.g. Mathe-online, youtube, ...)
☐ Face-to-face course provided by DHBW Mannheim
☐ Face-to-face course provided by another university
☐ Face-to-face course provided by my employer
☐ learning group
☐ other (open comment)
☐ no learning activity

**22 Would you like to work with the learning material once university courses have begun?** (radio button)

- yes
- no
- maybe

**23 Would you consider taking part in a survey at a later point in time, e.g. at the end of your second and fourth semester?** (radio button)

(these data will be anonymised, as well)

- yes
- no
- may be

## D.5 Learning strategies scale

**How much do you agree with these statements about your learning in the pre-course?** (strongly disagree / disagree / neutral / agree / strongly agree)

| | Item | source |
|---|---|---|
| 1 | *I always followed a certain learning schedule* | MSLQ #70,73 |
| 2 | *The learning material was so voluminous, I did not know where to begin** | own |
| 3 | *I studied in the evenings and on weekends, as well* | own |
| 4 | *I usually managed to keep to my schedule* | MSLQ #74,78 |
| 5 | *I just did not have enough time for learning** | MSLQ #77,80 |
| 6 | *I studied in a place where I could concentrate on learning* | MSLQ-modified |
| 7 | *I invested a lot of time into the study preparation* | own |
| 8 | *It was hard to learn alone** | MSLQ #45,50, removed |
| 9 | *I often felt so bored that I quit and did not finish the learning module.** | MSLQ-modified, removed |
| 10 | *Even if learning was hard, I finally managed to achieve what I had planned.* | MSLQ-modified, removed |

*reverse coded

*Dimensions: LS Learning Strategies (7 Items correlating on a common factor; 3 items removed)*

**Interpretation of scales**
LS (Learning Strategies) scale:
"strongly agree" (interpretation: participant has adequate strategies)
"agree" (interpretation: participant has some strategies)
"disagree" / "strongly disagree" (interpretation: participant has no strategies / is so good they are not needed)

# E Pre-study: group interviews

## E.1 Group interviews 2012

Three interviews carried out with students who had participated in the 2012 pre-course programme (self-study), two months after induction week.

| degree programme | n |
|---|---|
| Industrial Engineering | 7 |
| Electrical Engineering | 4 |
| Mechanical Engineering | 2 |

## E.2 Group Interviews 2013

Two interviews carried out with students who had participated participated in the 2013 pre-course programme (self-study), and students who had attended an additional face-to-face course.

| degree programme | n |
|---|---|
| Instustrial Engineering | 2 |
| Electrical Engineering | 2 |
| Computer Science | 2 |
| Mechanical Engineering | 1 |
| Mechatronics | 4 |

## E.3 Guiding questions

| | |
|---|---|
| Introduction | Hello, description of study background / interest |
| | Information on data privacy and anonymisation |
| Warm up question | Based on your experiences up to now (two months of university): How do you perceive mathematics lectures at university? Compared to mathematics taught at secondary school – are there any differences? |
| Workflow enrolment | When and from whom did you learn about the study preparation programme? |
| | Was all information easy to find and clearly structured? |
| Pre-test evaluation | When did you take the entry test (diagnostic pre-test), and where? |
| | Could you describe the situation in which you took the test? |
| | Were there any issues concerning difficulty, length, contents? |
| Diagnostic feedback evaluation | Was the feedback information useful for you? Did you know what to do once you received your test feedback? |
| Learning modules evaluation | When did you first got engaged with the learning modules? |
| | Did you have a special strategy for learning? |
| | Did you use the online or the printed material? Describe why you preferred one or the other. |
| | Did you experience any problems when working with the learning material? |
| Learning experience | Which problems occurred? Curricular? Comprehension? Motivational? |
| Effort | How much time did you spend learning? |
| Formative e-assessment | Many students voted for more exercises and self-tests: Do you agree? If yes, do you remember which type of exercises / tasks were especially helpful? |
| Post-test evaluation | Comparing pre-test and post-test: Were they similar in terms of difficulty? What was different? |
| | How were your feelings towards another assessment? |
| *keywords* | *difficulty, structure, usability, relevance to pre-test, relevance to school/university lectures, mathematical areas* |

## E.4 Extract: group interview statements

(translation from German by author)

**Difference between school and university**

"at school, I had this pretty tough math teacher, she always said, at university it won't be different, that's why we're doing this. … At school, you could ask the same idiotic question over and over again, it would have been responded to. Until you really got it. That I would call the only difference but according to pace and transfer, well, that might be connected with our teacher, she was really tough, I guess it depends on the teacher and the school as well."

*Male student, first year mechanical engineering, Abitur G9 (Gymnasium), Math grades: good, attitude towards mathematics: often had fun, pre-test result: 37%, post-test result: 64%*

„also, ich hatte schon an der Schule eine ziemlich harte Mathelehrerin, also, die hat immer gesagt, ja, an der Uni wird das nicht anders werden, deswegen machen wir das, … , man konnte an der Schule immer Fragen mehrfach stellen also, da wurde dann auch, wenn man manchmal die gleiche idiotische Frage zum dritten Mal schon gestellt hat, nochmal drauf eingegangen. Also bis mans wirklich verstanden hat. Also das würd ich also als einzigen Unterschied nennen aber so tempomäßig wars ähnlich und so transfermäßig eigentlich auch, also, das liegt vielleicht auch an der Lehrerin, also, wir hatten, echt eine ziemlich harte, also ich denk mal, das ist Lehrer- und Schul-unterschiedlich."

*Student, 1. Sem. Maschinenbau, Abitur G9 (Gymnasium) Rheinland-Pfalz, Mathenote: gut, Einstellung zu Mathe: hat oft Spaß gemacht, ET Ergebnis: 37%, KT Ergebnis: 64%*

"In the beginning, I could not cope at all because I was used to how it had been at school, meaning that I did not learn too much, I must admit, but these days, of course, I had to get out of that habit, and I go to the library three, four times a week and when I sit down and work through the Papula*, well then it does the trick."

Interviewer "That means you have to work hard for math?"

"I have invested quite a lot in math, yes."

*Male student, first year electrical engineering, Abitur G8 (Gymnasium), Math grades: good, attitude towards mathematics: ok, pre-test result: 35%, post-test result: 46%*
**Mathematics textbook*

„Also am Anfang bin ich gar nicht damit zurecht gekommen, weil ich ja alles noch so von der Schule gewöhnt bin, und da hab ich jetzt, sag ich mal, nicht so viel gelernt, aber das musste ich mir jetzt natürlich halt abgewöhnen, ja und seitdem ich jetzt wirklich immer drei-viermal die Woche in die Bibliothek gehe, und mich da mal hinsetz und hier den Papula durchgehe, ja, klappt das."

Interviewer „Das heißt der Aufwand für Mathe ist für Sie relativ groß?"

„Also ich hab relativ viel investiert in Mathe, ja."

*Student, 1. Sem. Elektrotechnik, Abitur G8 (Gymnasium) Baden-Württemberg, Mathenote: gut, Einstellung zu Mathe: in Ordnung, ET Ergebnis: 35%, KT Ergebnis: 46%*

### Learning modules: learning strategies

“But there was a final test to every learning module, wasn’t there? A script that went with the solutions to each item. … I kind of liked this. I used to start with taking these tests and then have a look at the scores. If I did not too good, I had another look at the script. But if I could handle the test, well I only skimmed through the script an if it was too complicated and I thought by myself, ok, you won’ t need this in the test anyway, then I left the proofs and all that aside.”

*Female student, first year industrial engineering, Abitur G9 (Gymnasium), Math grades: very good, attitude towards mathematics: often had fun, pre-test result: 48%, post-test result: 72%*

„Es gab aber doch auch zu jedem Thema so einen (Abschluss-) Test. Oder? Also so ein Aufgabenblatt mit Lösungen. … Das fand ich eigentlich ganz gut, weil ich hab immer einfach den Test gemacht und dann hab ich geschaut. Wenn ich also bei manchen viel nicht konnte, hab ich mir das Skript noch angeschaut. Aber wenn ich das eigentlich eh hinbekommen hab, dann ja, hat man vielleicht mal das Skript mal so kurz überflogen, und wenn es so ganz kompliziert war und ich mir dann gedacht hab, ok in den Aufgaben hat man es eh nicht gebraucht, da hab ich die Beweise und so auch einfach weggelassen.“

*Studentin, 1. Sem. Wirtschaftsingenieurwesen, Abitur G9 (Gymnasium) Hessen, Mathenote: sehr gut, Einstellung zu Mathe: hat oft Spaß gemacht, ET Ergebnis: 48%, KT Ergebnis: 72%*

### Diagnostic entry-test / pre-test

“… and if I may refer to this entry test, this math test, what really stood out in my first weeks at university, this test was very voluminous, I really have to say, and talking about depth and all the topics that were covered they were not as deep as this test has been. Maybe that was good, because you learned a bit more than you really have to, for your courses of studies.”

*Male student, first year electrical engineering, Abitur (Gymnasium), Math grades: average, attitude towards mathematics: often had fun, pre-test result: 32%, post-test result: 78%*

„… und wenn ich das jetzt gleich auf diesen Einstiegstest, auf diesen Mathetest beziehen kann, was mir jetzt hier in den ersten Wochen aufgefallen ist hier, dieser Test, der war sehr umfangreich, muss ich ehrlich sagen, und was wir bisher so in Mathe gemacht haben, was auch so die Tiefe betrifft von den Themen wie wir sie behandelt haben, die waren nicht so tief wie dieser Test gewesen ist. Das war vielleicht auch gut, dass man dann auch ein bisschen mehr gemacht hat als man machen muss, für das Studium.“

*Student, 1. Sem. Elektrotechnik, Abitur (Gymnasium) Brandenburg, Mathenote: befriedigend, Einstellung zu Mathe: hat oft Spaß gemacht, ET Ergebnis: 32%, KT Ergebnis: 78%*

### Diagnostic entry-test: feedback

“…Because you were asking about the learning recommendations that were given after the test, well I thought they were quite, hum, useless, the areas were rather broad and rough. I preferred to skim through the learning modules, had a look at it, and when I saw, that’s alright, I know it already, I just skipped a couple of pages and looked if I still understand it and took it from there.”

*Male student, first year industrial engineering, Abitur G9 (Gymnasium), Math grades: very good, attitude towards mathematics: ok, pre-test result: 42%, post-test result: 56%*

„…Sie haben ja auch gefragt wegen der Empfehlung, die man bekommen hat nach dem Test, und die fand ich jetzt, hm, ziemlich sinnlos, weil die Themengebiete die waren ja ziemlich grob und groß und umfassend. Da hab ich halt eher geschaut, ich hab mir das durchgelesen, wenn ich gesehen hab, das kann ich, hab ich halt ein paar Seiten übersprungen, und dann geschaut ob ich immer noch was versteh und dann halt je nachdem weiter gemacht.“

*Student, 1. Sem. Wirtschaftsingenieurwesen, Abitur G9 (Gymnasium) Baden-Württemberg, Mathenote: sehr gut, Einstellung zu Mathe: in Ordnung, ET Ergebnis: 42%, KT Ergebnis: 56%*

**Learning modules: pdf or online?**

“… and then I tried to do this on the computer, but I had to realise that it just didn’ t work, the picture on the screen was askew, it was extremely difficult to distinguish one part from another. Anyway, personally, I think it is really difficult to grasp these mathematical issues at the computer screen, so I decided to just download the PDF files, print them to paper and skip through.”

*Male student, first year industrial engineering, Abitur (Fachgymnasium), Math grades: good, attitude towards mathematics: ok, pre-test result:46%, post-test result: 56%*

„… und dann hab ich das probiert erst am PC zu bearbeiten, und da hab ich dann gemerkt, dass das überhaupt nicht funktioniert, weil da immer Verschiebungen auf meinem Bildschirm waren, dass das total schwierig war, das da auseinanderzuhalten, und auch persönlich, ich finds unheimlich schwierig so mathematische Sachen am PC zu erfassen, da hab ichs immer so gemacht, dass ich mir die PDFs runtergeladen hab, die ausgedruckt, die hab ich dann durchgeblättert.“

*Student, 1. Sem. Wirtschaftsingenieurwesen, Abitur (Fachgymnasium) Rheinland-Pfalz, Mathenote: gut, Einstellung zu Mathe: in Ordnung, ET Ergebnis: 46%, KT Ergebnis: 56%*

Student C “… well, what I liked were these, what do you call them, these interactive ... exactly, those I liked, but they weren’t available for the topics where I had performed … poorly.”

Student B “Yes, in general, I thought it was too bad that there weren’t online learning modules for each subject”

Student A “This interactive stuff was really good, the more of this, the better.”

*3 Students, first year electrical engineering*

Student C „… also was ich gut fand das waren diese, wie nennt man das, diese interaktiven … genau, die fand ich gut und die gabs halt genau nicht zu dem Thema wo ich halt dann … schlecht war..“

Student B „Ja, ich fands allgemein schade, dass es nicht zu allen Themen die Online Lernmodule gab“

Student A „Also die interaktiven Sachen waren immer richtig gut, also je mehr davon wäre umso besser.“

*3 Studierende 1. Sem. Elektrotechnik*

Student A: “Well, these online objects, they were, I would say, quite simple. Well, I did the first one and thought, hum, might be a bit too easy and then I had a look into the PDF files. They had far more difficult exercises in them, so I did those.”

Student B: “With me it’s like, I prefer something real between my hands. It’s like with a book and an e-book, I will always prefer the book.”

*2 Students, first year mechanical engineering*

Student B: „Ja also diese Online-Sachen, das waren ja, sage ich mal, recht simple Aufgaben. Also da hab ich dann das Erste gemacht und dann hab ich mir gedacht ‚Hmm ja doch ist schon ein bisschen zu leicht‘ und dann eben in die PDF´s reingeschaut. Da waren ja dann doch viel schwerere Aufgaben drin und dann eben die gemacht.

Student B: Und bei mir ist das so, ich mag lieber etwas Festes zwischen den Händen. Das ist genauso wie mit einem Buch und e-Book, ich zieh immer das Buch vor.

*2 Studierende 1. Sem. Maschinenbau*

### Unknown expressions

“Because I think, in this first test, there were so many things, in my opinion, so many expressions I don’t know, where I thought, ok, what’s that supposed to mean, scalar triple product, or something like that (laughs) never heard of, or what was it … gap in the definition or something like that, and I thought, what is this, I just never called it that way, I just didn’t know that this was the expression for it, because we just never did it that way.”

*Female student, first year industrial engineering, Abitur (Fachgymnasium), Math grades: good, attitude towards mathematics: often had fun, pre-test result: 37%, post-test result: 54%*

„Weil ich finde dass in diesem ersten Test viel drin war, was so, also für mich waren viele Begrifflichkeiten drin, die ich so einfach noch nie gehört hab, wo ich dann erst mal dachte, ok, weiß gar nicht, Spatprodukt, oder so, und ich dann so (lachen) hab ich noch nie gehört, oder was wars noch, ich glaub Definitionslücken oder so was, wo ich gedacht hab, hä, was ist denn das, das hab ich einfach nie so bezeichnet, das wusste ich einfach nie, dass das so heißt, mir hat der Ausdruck, wenn ich das aufschreib, hat mir das was gesagt, aber ich wusste nicht dass man das so bezeichnet, weil wir das einfach so nie gemacht haben.“

*Studentin, 1. Sem. Wirtschaftsingenieurwesen, Abitur (Fachgymnasium) Baden-Württemberg, Mathenote: gut, Einstellung zu Mathe: hat oft Spaß gemacht, ET Ergebnis: 37%, KT Ergebnis: 54%*

### Learning modules: difficulty level

“… Some of the scripts were really easy, well, at least from my point of view. I was done with them in about half an hour, an hour max. And others were, like I said, very complex and I kind of lost interest to work them all through, after a while. And, really, just skipped many parts. I think it should be more focused on exercises. My opinion. So I can control myself if I can do it, because, by only reading I can’t learn it.”

*Male student, first year industrial engineering, Abitur G9 (Gymnasium), Math grades: average, attitude towards mathematics: ok, pre-test result: 29%, post-test result: 50%*

„… es waren halt manche Skripte wirklich einfach, also, für mich jetzt persönlich einfach, die hatte ich dann nach einer halben Stunde, Stunde durch und manche waren halt, wie schon gesagt, komplex und da ist mir dann auch irgendwann die Lust vergangen, die durchzuarbeiten alle. Und, ganz genau, hab dann halt auch Teile überflogen. Also es sollte eigentlich mehr auf so Aufgaben aufgebaut werden. Find ich jetzt. Dass ich halt auch selbst kontrollieren kann ob ich das kann, weil mit Durchlesen allein kann ich es mir halt nicht wieder beibringen."

*Student, 1. Sem. Wirtschaftsingenieurwesen, Abitur G9 (Gymnasium) Baden-Württemberg, Mathenote: befriedigend, Einstellung zu Mathe: in Ordnung, ET Ergebnis: 29%, KT Ergebnis: 50%*

**Learning modules: too many mathematical proofs?**

Student A: "mathematical arguing, that's some thing of it's own. It's like in school, you always knew, here comes the proof, oh oh."

Interviewer "Do you do proofs in your lectures?"
Student A: "Not really."
Student B: "little."
Student C: "first of all definitions."
Student A: "Yes."
Student B: "In electrical engineering. There we have to find the definition ourselves."

*3 Students, first year electrical engineering*

Student C: „Beweis ist halt immer so eine Sache. Man kennts schon von der Schule, man wusste, wenn jetzt ein Beweis kommt, oh oh."

Interviewer „Brauchen Sie Beweise in der Vorlesung?"
Student C: „Eher weniger."
Student B: „Kaum."
Student A: „Erst mal definieren."
Student C: „Ja."
Student B: „In der Elektrotechnik. Da müssen wir uns die Formel eben selbst herleiten."

*3 Studierende 1. Sem. Elektrotechnik*

"Well let's say mathematical arguing, you will only need it if you're planning to become a mathematician, a lecturer, or whatever it is that mathematicians are doing. But I think for engineers, it is rather the practical relevance and the application that is important. I am really asking myself, if, later, I have to read a structural design, what do I need a mathematical proof for?!"

*Male student, first year mechanical engineering, Abitur G9 (Gymnasium), Math grades: good, attitude towards mathematics: often had fun, pre-test result: 37%, post-test result: 64%*

„Also sagen wir so, Beweise braucht man ja eigentlich nur, wenn man richtig in Richtung Mathematiker gehen will, also dann dozieren will. Was weiß ich was Mathematiker so alles machen, aber ich denke so für Ingenieure ist eher der Praxisbezug und die Anwendung wichtiger. Also da frag ich mich dann, was wenn ich später dann ein Tragwerk auslesen muss, wozu brauch ich jetzt einen Beweis?!"

*Student, 1. Sem. Maschinenbau, Abitur G9 (Gymnasium) Rheinland-Pfalz, Mathenote: gut, Einstellung zu Mathe: hat oft Spaß gemacht, ET Ergebnis: 37%, KT Ergebnis: 64%*

Student A: “Honestly, I have to say, these proofs I just skipped them, well, I have always been at war with proofs.”

Student B: “I would say, this formal way of approaching a problem is quite important, because, this is how we are doing it now. This preparatory course war quite important because otherwise, if I hadn’t done anything between school and university, that would have been fatal. That’s why I guess it is quite reasonable to have something like that.”

*2 Students, first year electrical engineering*

Student B: „Ja, für mich, ja also ich muss ehrlich sagen, diese Herleitungen, hab ich vollkommen überlesen, ähm, ja, ich stand schon immer auf dem Kriegsfuß mit Herleitungen.“

Student A: „Ich finde die formale Herangehensweise an Probleme schon wichtig, weil wir das jetzt auch immer so behandelt haben, und ich denke dass Mathe, dieser Mathevorbereitungskurs war schon wichtig, weil wenn ich jetzt denke, ich hätte zwischen der Schule und dem Studium gar nichts mehr gemacht, das wäre schon fatal gewesen. Deswegen denke ich schon dass es seine Berechtigung hat, sowas zu haben.“

*2 Studierende 1. Sem. Elektrotechnik*

**Learning modules: helpful or not?**

“I can only talk of myself and my personal deficit, but, yes, these scripts and exercises did help. But I really had to sit down and work hard, it took some time until I even understood the notation, and what’s behind it. Anyway, though I really sat down on a regular basis, I did not get through with all the material. There were, ten, I guess? I got until seven … and I am really not sure if I did exercise enough so that I could say, I am prepared to sit an examination.”

*Female student, first year industrial engineering, Abitur (Fachgymnasium), Math grades: good, attitude towards mathematics: often had fun, pre-test result: 37%, post-test result: 54%*

„Also ich find, aufgrund von meinem Defizit, also ich kann da ja jetzt nur von mir sprechen, haben‘s mir diese Übungsblätter oder Skripte schon gebracht. Allerdings musste ich mich auch wirklich hinsetzen und die durcharbeiten, dass ich erst mal diese theoretische Schreibweise versteh, auch versteh was dahintersteht, ich bin aber - und ich bin regelmäßig drangesessen - nicht durch alle Skripte durchgekommen. Es waren ja glaube ich – zehn? Ich bin bis sieben gekommen … da ist dann halt auch die Frage, inwieweit ich dann da schon Übungen genug dazu gemacht hab, dass ich das was ich gelesen hab und was ich versucht hab zu lernen auch wirklich umsetzen kann, wenn ich jetzt ne Aufgabe in der Vorlesung bekomme.“

*Studentin, 1. Sem. Wirtschaftsingenieurwesen, Abitur (Fachgymnasium) Baden-Württemberg, Mathenote: gut, Einstellung zu Mathe: hat oft Spaß gemacht, ET Ergebnis: 37%, KT Ergebnis: 54%*

“... I probably would have repeated some maths maybe two weeks before the start of university, in the middle of the practice phase where you are spending time with a lot of other things as well. And therefore, I guess, the first three weeks Math Lecture would have been a catastrophe. That’s why it was very helpful that I was back in mathematics just in time ...”

*Male student, first year mechanical engineering, Abitur G9 (Gesamtschule), Math grades: very good, attitude towards mathematics: often had fun, pre-test result: 48%, post-test result: 54%*

„… ich hätte wahrscheinlich mit ein bisschen Mathe wiederholen vielleicht zwei Wochen vor Uni-Beginn angefangen, sprich mitten in der Praxisphase drin, wo man dann doch auch noch die Zeit auf andere Dinge verwendet. Und dementsprechend wären, glaube ich, die ersten bis drei Wochen Mathe-Vorlesung katastrophal gelaufen. So war das dann schon wieder ganz hilfreich, dass man in der Mathematik wieder drin war..“

*Student, 1. Sem. Maschinenbau, Abitur G9 (Gesamtschule) Rheinland-Pfalz, Mathenote: sehr gut, Einstellung zu Mathe: hat oft Spaß gemacht, ET Ergebnis: 48%, KT Ergebnis: 54%*

**Motivation and activation**

“Well, only because of this [the entry-test] I realised that I might need to do something. Otherwise I would have went to the first lecture and would have been more or less shocked. And the first exam probably would not have worked out as good as it did. Therefore it was quite useful to have been shaken up a bit...”

*Male student, first year mechanical engineering, Abitur G9 (Gesamtschule), Math grades: very good, attitude towards mathematics: often had fun, pre-test result: 48%, post-test result: 54%*

„Also mir ist das erst dadurch bewusst geworden, dass man mal wieder was tun sollte. Sonst hätte ich mich glaub ich in die erste Vorlesung gesetzt und wäre erst mal ein bisschen geschockt gewesen. Klausur wäre bestimmt dann auch nicht, würde dann bestimmt auch jetzt nicht so gut ausfallen denke ich mal. Also war dann schon so gut mal wachzurütteln. Also in der Richtung fand ich das gut.“

*Student, 1. Sem. Maschinenbau, Abitur G9 (Gesamtschule) Rheinland-Pfalz, Mathenote: sehr gut, Einstellung zu Mathe: hat oft Spaß gemacht, ET Ergebnis: 48%, KT Ergebnis: 54%*

“Well, I did ok in the [control-] test. I have focused on those learning units I knew to be critical, because I did not learn them properly at school, or not at all. In order to become faster I did a couple of exercises, and that did it for the test.”

*Male student, first year electrical engineering, Abitur (Gymnasium), Math grades: average, attitude towards mathematics: often had fun, pre-test result: 32%, post-test result: 78%*

„Also bei mir ist er ganz gut gelaufen der Test. Ich hatte nur einzelne Module bearbeitet, wo ich wusste, die hab ich in der Schule nicht richtig gemacht oder gar nicht behandelt, und da hab ich lieber ein paar mehr Aufgaben gerechnet, um da fixer zu werden und das hat auch gut geklappt dann bei dem Test.“

*Student, 1. Sem. Elektrotechnik, Abitur (Gymnasium) Brandenburg, Mathenote: befriedigend, Einstellung zu Mathe: hat oft Spaß gemacht, ET Ergebnis: 32%, KT Ergebnis: 78%*

“This [entry-test result] was a shock, really, because I am used to be prepared for my mathematics classes, and to get the corresponding good grades. I was completely unprepared, and this result told me nothing, and this was a totally unusual situation for me.”

*Male student, first year mechanical engineering, Abitur G9 (Gesamtschule), Math grades: very good, attitude towards mathematics: often had fun, pre-test result: 48%, post-test result: 54%*

„Ja also für mich war (das Eingangstestergebnis) schon so ein bisschen ein Schock, weil ich hab normalerweise für den Mathe-Unterricht mich vorbereitet, und die Noten sind dann auch entsprechend gut ausgefallen. Da war ich halt total unvorbereitet, mit dem Ergebnis konnte ich erst mal nichts anfangen und das war dann auch eine komplett ungewöhnliche Situation.“

*Student, 1. Sem. Maschinenbau, Abitur G9 (Gesamtschule) Rheinland-Pfalz, Mathenote: sehr gut, Einstellung zu Mathe: hat oft Spaß gemacht, ET Ergebnis: 48%, KT Ergebnis: 54%*

“Well, if you go in there unprepared, this thing [the entry-test] is a punch in the gut. If you get a result like, you should more or less learn everything from A to Z, from Adam to Eve, that’s not so very effective, if you ask me. ... You do the test, submit it to the world wide web, and bang in your face you get the feedback.”

*Participant face-to-face pre-course 2013, vocational training and experience in a study-related professional field (Meisterabitur)*

„Also wenn man das jetzt so ganz unvorbereitet reingeht, das ist ein Schlag in die Magengrube das Ding. Wenn man da die Auswertung kriegt, Sie sollten sich eigentlich mit allem nochmal beschäftigen von A bis Z, von Adam bis Eva, ist das nicht so sonderlich zielführend , finde ich. ... Man macht einen Test, schickt das Ergebnis ins WorldWideWeb und der kommt zurück und es kommt die Faust aus dem Bildschirm geflogen.“

*Teilnehmer Präsenzseminar 2013, beruflich qualifiziert (Meisterabitur)*

“Well, ... I would say this ‘punch in the face’ was quite allright, because many of us feel secure, with nearly A grades in mathematics from the *Fachabi* [graduation from a subject-related secondary school], and then you do the test and score really poor, and that makes you wake up and think about study preparation, that’s what I did, eventually”.

*Participant face-to-face pre-course 2013, Fachabitur*

„Also … ich find den ‚Schlag ins Gesicht‘ eigentlich ganz gut, weil es geht vielen ja so, mit ner Fast Eins aus dem Fachabi, dann macht man den Test und kommt auf ein paar Prozent bloß, da wacht man halt doch auf und denkt vielleicht nochmal über die Studienvorbereitung nach, so wars bei mir zumindest.“

*Teilnehmer Präsenzseminar 2013, berufsbegleitendes Fachabitur*

“At the beginning [of the pre-course] we were provided with this structure of all mathematical topics, but at the moment I am lost, there’s this big fog and though sometimes a light shines through it remains rather foggy. I guess that I will have to do a lot of catching up at home, otherwise I am afraid I will not make it.”

*Participant face-to-face pre-course 2013, Fachabitur*

„Wir haben am Anfang die Gliederung bekommen was wir jetzt alles machen, aber noch fehlt mir so die Übersicht, da ist so ein Riesen Schleier drüber, wie so ein Nebelfeld, und es kommt zwar so langsam Licht in dieses Feld aber es ist halt an und für sich noch ziemlich neblig, also und ich glaub dass auch ziemlich viel Zeit zu Hause am Schreibtisch folgen wird. Anders klappt das gar nicht!“

*Teilnehmer Präsenzseminar 2013, berufsbegleitendes Fachabitur*

# F Quantitative Analyses

## F.1 Relations between exam scores and cumulated GPA (2011)

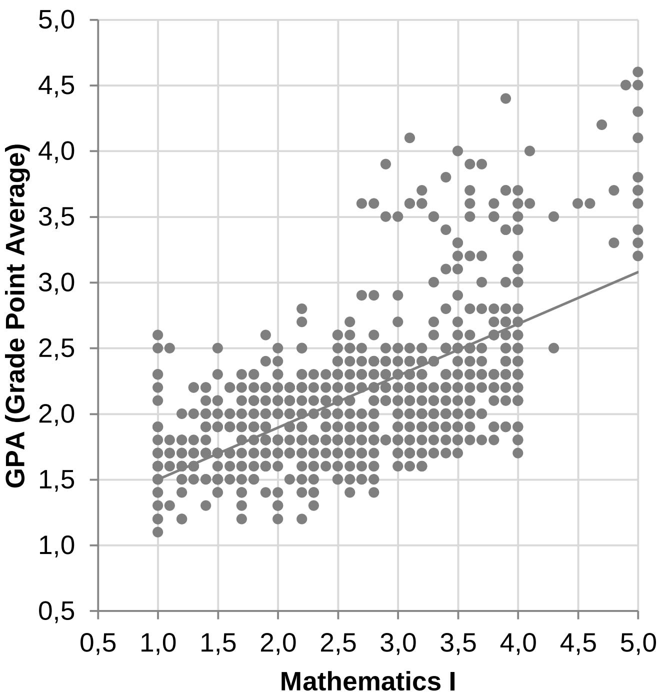
**Correlations cumulated GPA and exam scores, cohort 2011, participants at least one test (pre-or posttest) (n = 660)**

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cumulated GPA | | | | | | | | | | | | |
| 1 | Mathematics I | .62 | | | | | | | | | | | |
| 2 | Mathematics II | .66 | .60 | | | | | | | | | | |
| 3 | Electrical Engineering I | .63 | .46 | .47 | | | | | | | | | |
| 4 | Physics | .57 | .20 | .29 | .29 | | | | | | | | |
| 5 | Thermodynamics | .45 | .30 | .33 | .70 | .38 | | | | | | | |
| 6 | Feedback Control Systems | .56 | .29 | .40 | .34 | .23 | .27 | | | | | | |
| 7 | Theoretical computer science I | .59 | .64 | .53 | | .19 | | | | | | | |
| 8 | Engineering mechanics I | .62 | .49 | .46 | .46 | .33 | .21 | .23 | | | | | |
| 9 | Construction I | .34 | .24 | .19 | | .15 | .23 | -.01 | | .29 | | | |
| 10 | Mechanical Engineering I | .61 | .55 | .40 | .37 | .30 | | | | | | | |
| 11 | Seminar paper | .44 | .20 | .23 | .12 | .17 | .17 | .18 | .13 | .25 | .13 | .04 | |
| 12 | Final project | .59 | .21 | .19 | .13 | .22 | .11 | .22 | .10 | .17 | .06 | .36 | .26 |

correlation is significant at the 0.01 level (2-tailed)
correlation is significant at the 0.05 level (2-tailed)

**Correlation between cumulated GPA and Mathematics I, cohort 2011, participants at least one test (pre-or posttest) (n = 666)**

Pearson $r$ = .62



**Multiple regression cumulated GPA and three exam scores, cohort 2011**

| | $B$ | Stand. err. | $\beta$ | $t$ | sig. | 95% conf. Interv. $B$ lower | upper |
|---|---|---|---|---|---|---|---|
| (constant) | 2.321 | .080 | | 28.921 | .000 | 2.163 | 2.479 |
| Mathematics I (rev) | .088 | .020 | .193 | 4.377 | .000 | .049 | .128 |
| Mathematics II (rev) | .166 | .022 | .334 | 7.465 | .000 | .123 | .210 |
| Physics (rev) | .213 | .018 | .423 | 11.875 | .000 | .178 | .248 |

| $R^2$ | adj. $R^2$ | $F$ | $df$ | | sig. |
|---|---|---|---|---|---|
| .523 | .519 | 149.591 | 3 | 410 | .000 |

| | |
|---|---|
| Durbin-Watson statistics | 1.749 |

*Dependent variable cumulated GPA, 2011:Multiple linear regression with IVs Mathematics I, Mathematics II, Physics (n = 414; excluded: excluded: 25 students who had voluntarily withdrawn and 10 outliers with a Mahalanobis distance > 9)*

# F.2 Mathematics I performance
## Pre-course participants versus non-participants (2011-2016)

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Pre-course participation | 497 | 626 | 574 | 578 | 519 | 583 |
| No pre-course participation | 198 | 167 | 112 | 96 | 141 | 164 |
| Total | 695 | 793 | 686 | 674 | 660 | 747 |

*Number of pre-course participants versus non-participants in Mathematics I exam (2011-2016)*

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Pre-course participation | 2.6 | 2.6 | 2.8 | 2.8 | 2.7 | 2.7 |
| No pre-course participation | 2.8 | 3.1 | 3.2 | 3.3 | 3.3 | 3.2 |
| Total | 2.7 | 2.7 | 2.9 | 2.8 | 2.9 | 2.8 |

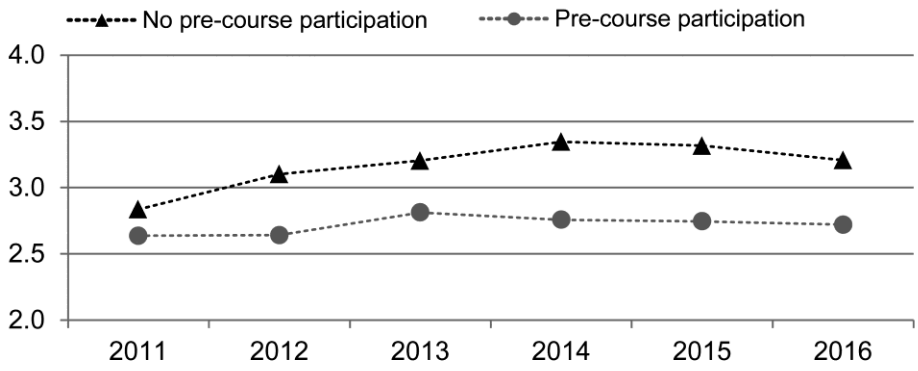
*Mathematics I average grades of pre-course participants versus non-participants (2011-2016) (grades measured on a linear scale from 1 (=A) to 5, an exam graded > 4.0 was failed)*

ANOVA Mathematics I grades
2011: $F(1, 693) = 6.5$, $p < .05$
2012: $F(1, 791) = 33.5$, $p < .001$
2013: $F(1,684) = 13.6$; $p < .001$
2014: $F(1, 672) = 28.3$, $p < .001$
2015: $F(1, 658) = 39.7$, $p < .001$
2016: $F(1, 745) = 29.1$, $p < .01$

| | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|
| Pre-course participation | 97.2 | 97.1 | 92.7 | 95.0 | 96.1 | 94.7 |
| No pre-course participation | 95.5 | 91.0 | 84.8 | 77.1 | 85.8 | 83.5 |
| Total | 96.7 | 95.8 | 91.4 | 92.4 | 93.9 | 92.2 |

*Mathematics I pass rates of pre-course participants versus non-participants (2011-2016)*

Chi-square tests pass rate:
2011: $n = 695$; $df = 1$; $\chi^2 = 1.322$; $p = .250$
2012: $n = 793$; $df = 1$; $\chi^2 = 12.327$; $p < .001$
2013: $n = 686$; $df = 1$; $\chi^2 = 7{,}368$; $p < .01$
2014: $n = 674$; $df = 1$; $\chi^2 = 37.712$; $p < .001$
2015: $n = 660$; $df = 1$; $\chi^2 = 20.785$; $p < .001$
2015: $n = 747$; $df = 1$; $\chi^2 = 22.204$; $p < .001$




*Mathematics I average grades of pre-course participants versus non-participants (2011-2016) (grades measured on a linear scale from 1 (=A) to 5, an exam graded > 4.0 was failed)*

# F.3 Multiple regressions with Mathematics I (2011-2016)

**Multiple linear regression Mathematics I: 2011**

| | *B* | *SE B* | β |
|---|---|---|---|
| Constant | 1.87 | 1.16 | |
| 1 Gender | -.02 | .14 | -.01 |
| 2 Age | -.06 | .06 | -.09 |
| 3 Gap school / university | .12 | .07 | .14 |
| 4 Federal state: R-P | .13 | .12 | .06 |
| 4 Federal state: Hesse | .00 | .12 | .00 |
| 4 Federal state: NRW | -.01 | .16 | .00 |
| 4 Federal state: Bavaria | .00 | .13 | .00 |
| 5 Type of school: S-GYM | .04 | .19 | .02 |
| 5 Type of school: G-GYM | .21 | .18 | .09 |
| 6 Math. grades: good | .16 | .12 | .09 |
| 6 Math. grades: very good | .26 | .16 | .13 |
| 7 Secondary school GPA | .30 | .11 | .16* |
| Pre-test score (%) | .03 | .00 | .36** |
| Gain score (%) | .01 | .00 | .16** |
| $R^2$ / $R^2$ adj. | .28 (.25) | | |
| $F$ for change in $R^2$ | 10.09** | | |
| Durbin-Watson statistics | 1.681 | | |

*B*: unstandardised regression coefficient; *SE B*: standard error; β: standardised regression coefficient; significance levels: *p < .05; **p < .01

[a]Federal state Baden-Wuerttemberg = baseline; [b]Vocational school = baseline versus S-GYM (subject-related Gymnasium) and G-GYM (Gymnasium); [c]Math. grades poor = baseline

*Regression analysis for variables predicting Mathematics I (n = 383). Students' preconditions when entering university, diagnostic pre-test score and gain score*

**Multiple linear regression Mathematics I: 2012**

| | *B* | *SE B* | β |
|---|---|---|---|
| Constant | .97 | .75 | |
| 1 Gender | .33 | .10 | .13** |
| 2 Age | -.01 | .03 | -.02 |
| 3 Gap school / university | .21 | .06 | .19** |
| 4 Federal state: R-P | .12 | .09 | .06 |
| 4 Federal state: Hesse | .04 | .10 | .02 |
| 4 Federal state: NRW | -.09 | .12 | -.03 |
| 4 Federal state: Bavaria | .21 | .15 | .06 |
| 5 Type of school: S-GYM | .07 | .14 | .03 |
| 5 Type of school: G-GYM | .25 | .13 | .12 |
| 6 Math. grades: good | .22 | .11 | .12* |
| 6 Math. grades: very good | .37 | .14 | .18** |
| 7 Secondary school GPA | .30 | .09 | .18** |
| Pre-test score (%) | .02 | .00 | .22** |
| Gain score (%) | .02 | .00 | .19** |
| | | | |
| $R^2$ / $R^2$ adj. | .29 (.27) | | |
| $F$ for change in $R^2$ | 15.08** | | |
| Durbin-Watson statistics | 2.026 | | |

*B*: unstandardised regression coefficient; *SE B*: standard error; β: standardised regression coefficient; significance levels: *p < .05; **p < .01

[a]Federal state Baden-Wuerttemberg = baseline; [b]Vocational school = baseline versus S-GYM (subject-related Gymnasium) and G-GYM (Gymnasium); [c]Math. grades poor = baseline

*Regression analysis for variables predicting Mathematics I (n = 524). Students' preconditions when entering university, diagnostic pre-test score and gain score*

**Multiple linear regression Mathematics I: 2013**

| | *B* | *SE B* | β |
|---|---|---|---|
| Constant | -1.13 | .88 | |
| 1 Gender | .17 | .11 | .06 |
| 2 Age | .05 | .04 | .08 |
| 3 Gap school / university | .01 | .06 | .01 |
| 4 Federal state: R-P | .16 | .11 | .07 |
| 4 Federal state: Hesse | .18 | .11 | .08 |
| 4 Federal state: NRW | -.08 | .12 | -.03 |
| 4 Federal state: Bavaria | .15 | .16 | .04 |
| 5 Type of school: S-GYM | .41 | .17 | .14* |
| 5 Type of school: G-GYM | .46 | .15 | .19** |
| 6 Math. grades: good | .07 | .11 | .04 |
| 6 Math. grades: very good | .20 | .15 | .09 |
| 7 Secondary school GPA | .51 | .10 | .27** |
| Pre-test score (%) | .02 | .00 | .36** |
| Gain score (%) | .01 | .00 | .08* |
| | | | |
| $R^2$ / $R^2$ adj. | .38 (.36) | | |
| $F$ for change in $R^2$ | 20.24** | | |
| Durbin-Watson statistics | 1.748 | | |

*B*: unstandardised regression coefficient; *SE B*: standard error; β: standardised regression coefficient; significance levels: *p < .05; **p < .01

[a]Federal state Baden-Wuerttemberg = baseline; [b]Vocational school = baseline versus S-GYM (subject-related Gymnasium) and G-GYM (Gymnasium); [c]Math. grades poor = baseline

*Regression analysis for variables predicting Mathematics I (n = 482). Students' preconditions when entering university, diagnostic pre-test score and gain score*

**Multiple linear regression Mathematics I: 2014**

| | *B* | *SE B* | β |
|---|---|---|---|
| Constant | -.76 | .97 | |
| 1 Gender | .17 | .12 | .06 |
| 2 Age | .05 | .04 | .09 |
| 3 Gap school / university | -.07 | .06 | -.08 |
| 4 Federal state: R-P | .05 | .11 | .02 |
| 4 Federal state: Hesse | -.05 | .11 | -.02 |
| 4 Federal state: NRW | -.07 | .14 | -.02 |
| 4 Federal state: Bavaria | .37 | .15 | .11* |
| 5 Type of school: S-GYM | -.10 | .16 | -.04 |
| 5 Type of school: G-GYM | .13 | .16 | .06 |
| 6 Math. grades: good | .17 | .11 | .08 |
| 6 Math. grades: very good | -.06 | .14 | -.02 |
| 7 Secondary school GPA | .38 | .10 | .20** |
| Pre-test score (%) | .03 | .00 | .49** |
| Gain score (%) | .01 | .00 | .18** |
| | | | |
| $R^2$ / $R^2$ adj. | .35 (.33) | | |
| $F$ for change in $R^2$ | 17.47** | | |
| Durbin-Watson statistics | 2.001 | | |

*B*: unstandardised regression coefficient; *SE B*: standard error; β: standardised regression coefficient; significance levels: *p < .05; **p < .01

[a]Federal state Baden-Wuerttemberg = baseline; [b]Vocational school = baseline versus S-GYM (subject-related Gymnasium) and G-GYM (Gymnasium); [c]Math. grades poor = baseline

*Regression analysis for variables predicting Mathematics I (n = 465). Students' preconditions when entering university, diagnostic pre-test score and gain score*

**Multiple linear regression Mathematics I: 2015**

| | *B* | *SE B* | β |
|---|---|---|---|
| Constant | .96 | .98 | |
| 1 Gender | .03 | .12 | .01 |
| 2 Age | -.04 | .05 | -.07 |
| 3 Gap school / university | .12 | .06 | .16 |
| 4 Federal state: R-P | .10 | .12 | .05 |
| 4 Federal state: Hesse | -.05 | .12 | -.02 |
| 4 Federal state: NRW | .10 | .15 | .03 |
| 4 Federal state: Bavaria | .16 | .14 | .06 |
| 5 Type of school: S-GYM | .21 | .18 | .08 |
| 5 Type of school: G-GYM | .45 | .16 | .21* |
| 6 Math. grades: good | .21 | .12 | .11 |
| 6 Math. grades: very good | .39 | .16 | .18* |
| 7 Secondary school GPA | .36 | .11 | .20** |
| Pre-test score (%) | .02 | .00 | .24** |
| Gain score (%) | .01 | .00 | .13* |
| | | | |
| $R^2$ / $R^2$ adj. | .27 (.25) | | |
| $F$ for change in $R^2$ | 10.21** | | |
| Durbin-Watson statistics | 1.980 | | |

*B*: unstandardised regression coefficient; *SE B*: standard error; β: standardised regression coefficient; significance levels: *p < .05; **p < .01

[a]Federal state Baden-Wuerttemberg = baseline; [b]Vocational school = baseline versus S-GYM (subject-related Gymnasium) and G-GYM (Gymnasium); [c]Math. grades poor = baseline

*Regression analysis for variables predicting Mathematics I (n = 398). Students' preconditions when entering university, diagnostic pre-test score and gain score*

**Multiple linear regression Mathematics I: 2016**

| | *B* | *SE B* | β |
|---|---|---|---|
| Constant | .17 | 1.01 | |
| 1 Gender | .16 | .11 | .06 |
| 2 Age | -.04 | .04 | -.07 |
| 3 Gap school / university | .17 | .05 | .25** |
| 4 Federal state: R-P | .04 | .11 | .02 |
| 4 Federal state: Hesse | -.13 | .12 | -.05 |
| 4 Federal state: NRW | -.23 | .14 | -.08 |
| 4 Federal state: Bavaria | -.14 | .16 | -.04 |
| 5 Type of school: S-GYM | .09 | .17 | .03 |
| 5 Type of school: G-GYM | .40 | .16 | .18* |
| 6 Math. grades: good | .03 | .12 | .02 |
| 6 Math. grades: very good | .09 | .16 | .04 |
| 7 Secondary school GPA | .62 | .10 | .36** |
| Pre-test score (%) | .02 | .00 | .26** |
| Gain score (%) | .01 | .00 | .03* |
| | | | |
| $R^2$ / $R^2$ adj. | .31 (.29) | | |
| $F$ for change in $R^2$ | 13.64** | | |
| Durbin-Watson statistics | 1.923 | | |

*B*: unstandardised regression coefficient; *SE B*: standard error; β: standardised regression coefficient; significance levels: *p < .05; **p < .01

[a]Federal state Baden-Wuerttemberg = baseline; [b]Vocational school = baseline versus S-GYM (subject-related Gymnasium) and G-GYM (Gymnasium); [c]Math. grades poor = baseline

*Regression analysis for variables predicting Mathematics I (n = 440). Students' preconditions when entering university, diagnostic pre-test score and gain score*

# G First year student interviews

## G.1 Guiding questions

| | |
|---|---|
| Introduction | Hello, description of study background / interest |
| | Information on data privacy and anonymisation |
| Personal background | Degree programme, employer, age, federal state , type of school, ... |
| | Why this degree programme? Personal interest / job / career, ... |
| | When did you decide to study engineering? |
| | Was mathematics at any time relevant for this decision? |
| | What did you like / not like regarding mathematics at school? |
| | How did you perform in mathematics at school? |
| Relevance of mathematics for degree programme / practical applications | What is your favourite subject at university? |
| | Do you need mathematics there? |
| | What are the main differences between mathematics lectures at university and mathematics class school? (if any) |
| | Practical applications part of mathematics teaching at school? |
| | Practical applications part of mathematics lectures at university? |
| | Can you give an example for when you realized how mathematics was useful for an engineering course? |
| Pre-course | How did you find out about the pre-course? |
| | Where did you take the pretest? |
| | How would you describe the test's difficulty level? |
| | Did you have any problems answering the test? |
| | Was the feedback helpful? |
| Additional course | Did you enrol in an additional course? |
| | Which one? |
| | Do you remember which learning modules you worked through? |
| | How did you like the course? |
| | - The learning material? |
| | - The e-tutor? |
| | - Group work? |
| Practice | How did you learn individually? |
| | - Did you have an individual schedule? A routine? |
| | - How did your average learning session look like? |

| | |
|---|---|
| | - How many hours per week? |
| | - Time management: did you manage? Did you feel overwhelmed? |
| | Were the learning environment / the e-tutor / the peer group helpful / supportive if you felt overburdened? |
| Peers | Did you participate in a learning group? |
| | How was this group organised? |
| Anonymity | How did you feel in the web-based environment regarding data privacy? Did you feel monitored? If yes, was this good or bad? |
| Motivation | What did you find motivating / demotivating? |
| | Did you think of the post-test when learning? |
| | Were you afraid of the post-test? |
| Application of mathematics in pre-course | Practical applications / simple problems / proofs: which type of questions did you prefer? |
| Practice today | How is your learning routine at university? Your way of learning: did it change from school / pre-course to university? |
| | Do you feel confident that you can cope with the demands in mathematics / other subjects? |
| | Do you get any support by the university / peers / your environment? |
| | Did you have any training regarding learning techniques, time management, …? |
| | What kind of support would you like to get? |
| Relate pre-course contents to university | Do you think what you learned in the pre-course is useful for your degree programme? |
| | In what respect? Which learning contents in particular? |
| | Do you think that you will need your mathematics knowledge for your future work as an engineer? |
| | From your point-of-view as a first year student: how would you advise a prospective engineering student regarding the demands in mathematics? |

## G.2 Interview summaries

**recording_A: “Anna”**

| | |
|---|---|
| Computer science student, age 31, secondary school: non EU | |
| Secondary school certificate: | 1.9 (good) |
| Mathematics grades: | very good |
| Mathematics attitude: | liked mathematics |
| Pre-test result: | 49.4 |
| Gain score: | 17.3 |
| Pre-course participation: | e-tutoring + face-to-face course |
| number of online test attempts: | 5 |
| Mathematics I: | 1.3 (very good) |

*Summary:* Anna has already studied languages and worked as an interpreter in XXX. Not feeling adequately paid and feeling she had no perspectives for professional growth she and her husband chose to change their career lines. Both applied to companies in the Mannheim area and were accepted for the dual degree programme. Anna chose computer science because she always liked programming. She even did extra courses (C++, web engineering) and tried to get into programming jobs but found that employers mainly seek for “proper” computer scientists. She never had problems with mathematics at school but she graduated from secondary school in 2003, therefore many things were forgotten (“it nearly completely slipped my mind”). Having attended school in Russia she also learned mathematics in another language and a different tradition of teaching. Therefore she was aware that she would need some mathematics preparation. Her employer, a German bank, advised her to take this issue seriously as they had “lost” four out of five computer science students in the previous year[1]. The employer paid for a face-to-face course and gave students time to learn during the apprenticeships prior to the degree programme. The employer also brought them in contact with a former student who had excelled in mathematics.

Anna participated in the face-to-face course and in the e-tutoring course, as well (“And I was surprised, because I liked the online course better and I gained much more from it” “the online course was much more focused on rehearsal. You had to submit something every week but you also had enough time to answer the problems. And when you were ready and uploaded your answers you immediately got feedback.”)

She studied eight (out of ten) learning modules (“I did not have the time to do the ‘Logic’ module, which I regret, because now I am the only one without any knowledge in statistics”).

During the study preparation phase she always learned alone (“ok, sometimes I asked my husband or someone who knows maths”). Today, she mainly learns in a study group (“we also prepare for exams in a study group. We also helped those who did not pass their first exam”)

[1] These students had to leave university after too many failures. Note that each exam may be failed twice (first and second attempt), the last chance is an oral examination. If this is failed, as well, the student cannot proceed with the programme.

She cannot remember the pre-course problems in detail but she likes mathematics problems with practical applications and dislikes mathematical proofs. (“Proofs are very time consuming. You cannot say: I sit down for one, two hours and then I’m through with the exercise sheet. For a normal problem you need ten minutes and then you’re done, but for a proof you need a couple of days and you’re still not finished”)

Her favourite subject is software engineering; she likes to “have a product one can showcase” and to “see what one has learned”. She thinks mathematics is relevant in all of her other subjects (“mathematics is everywhere”; “we have no subject that is irrelevant for our job”).

Even though her timetable is already packed (ten of her statements can be related to lack of time) she wants to do even more (“I always research in which direction I might go - after graduation - what might be useful for my career. I also want to take Coursera classes”)

Anna’s approach to learning mathematics: do as many exercises as possible, learn in groups, seek help (but also help others). Her focus is quite strategic (grades / job perspectives). Her interest in understanding mathematics appears to be triggered by that focus – knowing mathematics is an important factor for her future job.

**recording_B: “Ben”**

| Computer science student, age 20, *Abitur, gymnasium* | |
|---|---|
| Secondary school certificate: | 2.5 (ok) |
| Mathematics grades: | very good |
| Mathematics attitude: | liked mathematics |
| Pre-test result: | 48.2 |
| Gain score: | 11.8 |
| Pre-course participation: | e-tutoring |
| number of online test attempts: | 4 |
| Mathematics I: | 2.9 (medium) (after one failed attempt) |

*Summary:* Ben had computer science at school and liked it a lot and therefore decided to study this subject. He also was quite good at mathematics. They had an information day at their school where he learned about DHBW. He liked the concept (“I am not the type who likes to learn theoretically, I prefer to apply things, try things out”) and applied and was accepted.

Some pre-test contents were new to him, or were forgotten (“trigonometry, addition theorems”), he therefore repeated those. He found the pre-test helpful because it raised his awareness (“otherwise I would have walked right into the first lecture and would have been struck dead.”). Mathematics at university for him is completely different from mathematics at school (“you just did problems. The rules were never questioned it was like ‘this is the rule, that’s how it works, now you can apply it.’ And here you have to prove everything, they just show once how it might work in theory, but not how to apply it. We have these exercise sheets but during the lectures we never do any problems ourselves.” “In the lecture it is like ‘this is it’. Then there come three pages of proof, and if you look the other way for one second, you can no longer follow”)

He found some of the pre-course mathematics problems really good (“it helped to understand ‘how can I apply this’”), but sometimes he thought “Do you really calculate it like this in real life?”

He did not put too much effort into the pre-course (“two hours a day for two or three weeks ... it’s not that I sat down for three months and learned eight hours a day”), he learned alone and sometimes used Google or Youtube (“you can find some good videos there, it’s easy to learn for yourself”). At university, he made the “fatal error” to start learning three weeks before the exam (he then failed Mathematics I in the first attempt). Now he summarises his lectures in the evenings in order to be prepared “when the exams are dawning”.

He prefers to learn alone (“when I study in a group, I have often experienced that you easily let yourself be distracted, stray away from the subjects and then in the end you have been sitting there for four hours and have hardly learnt anything.”) but also asks his peers when he does not understand something. They often talk about their courses when travelling to / from university or in their free periods.

His favourite subject is JAVA and he also likes the project work that has just started. He sometimes can relate his mathematics lectures to other subjects (“there are functions that you can better understand with a mathematical background, like ‘ok, this is why that happens right now’, but you do not need it *directly* for programming” “in Logic we had these relations, you probably can use that in relational database systems, but otherwise I guess I will not be needing what I learned in mathematics at work”).

Ben’s approach to mathematics learning is quite strongly motivated by exam dates but he also wants to have leisure time and appears not extremely stressed (“ok, when the exams are coming, then you’re feeling more and more your guilty conscience when you do something else than learning. ... But when I am motivated on one day, I allow myself a break on the next day”)

**recording_C: “Chris”**

| | |
|---|---|
| Computer science student, age 29, secondary school: non EU | |
| Mathematics grades: | ok |
| Mathematics attitude: | liked mathematics |
| Pre-test result: | 27.1 |
| Gain score: | 10.7 |
| Pre-course participation: | self-study |
| number of online test attempts: | 1 |
| Mathematics I: | 1.5 (good) |

*Summary:* Chris was born in XXX and came to Germany four years ago. Both his mathematics grades at school and his pre-test results are not very promising, but he wrote a good Mathematics I exam. It appears that he has more problems understanding and communicating in German than understanding mathematics. He achieved a degree in chemistry in his home country but wants to study computer science in order to make a living in Germany.

He studied alone with the pre-course material and continues to learn alone at university. He is quite determined and spends his evenings and weekends at the university’s library. He is disappointed that he never meets other students at the library. He appears to be a little bit isolated and would like to participate in a learning group but has not yet been able to find one.

Although his pre- and posttest results were poor, Chris considered the pre-course learning contents as very easy and he did not invest very much time into his study preparation ("An hour here or there. Taken together: one day, I assume"). Unlike his fellow students, he prefers mathematical proofs to word problems ("Well, I like proofs a lot" ... "Proofs are a challenge. There are problems that are just fun, you enjoy solving them. Whereas a proof, that is a challenge. You have to research a lot in the internet, in books, until you understand it and write it down. And you are proud when you can present it at the blackboard")

For Chris, the main difference between secondary school and university is the lack of guidance ("At school you get problems and do them, but here you have to try and study alone, look for literature, find solutions. And structure your answers in a logical way.")

Mathematics for him is a means to develop logical thinking, which is relevant for nearly all his other subjects ("syntax in programming" ... "mathematics is everywhere")

Chris' approach to mathematics learning: making summaries of the script, doing exercises. He is the only student who reported to look for literature in the library, and not just search the internet. He is quite self-confident regarding his mathematics abilities but, due to his language problems, appears to be insecure regarding other subjects ("Sometimes I am scared, because, either you pass or you are exmatriculated. But you have to make it. Yes.").

**recording_D: "Daniel"**

| Computer science student, age 19, *technical gymnasium* | |
|---|---|
| Secondary school certificate: | 2.2 (good) |
| Mathematics grades: | good |
| Mathematics attitude: | liked mathematics |
| Pre-test result: | 47.1 |
| Gain score: | -20.4, improvement in arithmetic, logic, vectors (from poor to medium) in all other issues decrease, zero in functions, geometry, trigonometry, and continuous functions |
| Pre-course participation: | self-study, three weeks, forgot which learning modules he studied |
| number of online test attempts: | - |
| Mathematics I: | 2.8 (medium) (after one failed attempt) |

*Summary:* Daniel decided during secondary school to study computer science, he participated in an open day at the company he later applied to. He also did an apprenticeship at an IT company during ninth grade. He liked mathematics at school and was good at it.

His company advised him to participate in the pre-course ("we also have a mentoring system at our company and they already told us what to expect"). He worked through the learning modules that were suggested in the pre-test feedback but has forgotten which contents exactly. He was disappointed that he performed poorly in the post-test and appeared to be uncomfortable talking about this result ("I don't know if this was because of being nervous or something. Yes, the test results were worse than I expected them to be."). However, he claimed that he had not felt under pressure to perform better in the post-test and he considered this test as more difficult than the first one.

He learned alone during his study preparation. He took the pre-test quite early (in July) but is quite vague about his study time ("2-3 hours per week maybe", "I don't remember when I started learning", "in the end I only had three weeks left to learn") but he thinks this was sufficient ("if you really *want* to do something then you will find the time. You just have to plan it.").

Now he shares a study group with other students from the same company. There is a support system provided by the company ("If there is a problem we can talk to our managers, or with elder students. I think the support is really good") but he seems to be reluctant to share his problems with his managers (or the interviewer). He does not mention that he did not pass Mathematics I.

Daniel prefers word problems to other problems ("I'd say this practical approach was the best and it's much more interesting than if you have theoretical question. And it does not matter if its computer science or any other application. What's important is that you have an example, that you can imagine what it's used for."). The biggest difference to mathematics at school is the general approach ("at school, I would say, you also had much more time for explanations, and for doing problems, and for practising. Here you have to do that all on your own").

Daniel's favourite subjects are JAVA and digital technology. He can see the application of mathematics knowledge for his profession ("for example, in security, the mathematics we are doing helps a lot. Especially in process optimisation").

His approach to mathematics learning (see above): making summaries of the script, doing exercises. He participates in a learning group but this group is organised by his employer and he does not mention if this group is helpful for him or not. He seems to do everything he is asked to do but seldom expresses an individual concern. He often answers vaguely and evades outright positive or negative statements, sometimes relativising his own statements ("in the pre-course there also was this YouTube lecture from this professor from Heidelberg. I thought that was quite positive. And we looked at some other videos during our learning session because it was quite well explained." "but in general the internet was not much used, only if you had questions and did not know how to solve a problem ... then you used it") ("what we are doing here is somehow like school mathematics but of course it is completely different")

He has forgotten about the pre-course learning contents and how much he studied but remembers his poor post-test result which seems to bother him. Daniel was used to be "good at mathematics" and now seems to be unsure of his abilities.

**recording_E: “Eric”**

| Computer science student, age 20, *Abitur, gymnasium* | |
|---|---|
| Secondary school certificate: | 2.2 (good) |
| Mathematics grades: | very good |
| Mathematics attitude: | favourite subject |
| Pre-test result: | 41.2 |
| Gain score: | 12.2 |
| Pre-course participation: | self-study |
| number of online test attempts: | 5 |
| Mathematics I: | 3.3 (medium to poor)(after one failed attempt) |

*Summary:* Eric was good at mathematics at school and also had computer science and wanted to have a practical element in his course, therefore went for a dual degree programme. He preferred mathematics at school (“definitely at school”), at university he is missing the application (“sometimes they give you examples but you do not understand directly how you can really use this”)

He considered the pre-test feedback as helpful but could not remember what his learning recommendations were. He did not invest too much time into his study preparation (“maybe ten to fifteen hours as a whole”). He also forgot if he studied with the PDF or online versions but during the interview it comes back to him (“in the online versions you get this immediate feedback, I preferred that”)

He found the pre-course neither particularly easy, difficult, or interesting (“near the end it often was like ‘ok, I am doing this because it is important’ but I lost motivation at some point”). Knowing that there would be a post-test made him try a little harder (“that encouraged me to improve my result”) and he was satisfied that he had managed.

Eric’s approach to learning mathematics has changed since secondary school (“Well, in school, especially in maths, it was enough for me personally to pay attention, to participate in class. And yes, maybe I had to look at one, two things again, about formulas or something. But I never had to do a lot more work at home, it was sufficient but is definitely not sufficient here.”). In the first semester he “learned the hard way” that this approach was not sufficient. He failed Mathematics I and will have to resit this exam.

Now he recapitulates the lecture in the evenings and does the exercises provided by the lecturer and also started to meet up with a group of students that take the same train. His employer / colleagues have offered support but so far he has not made use of this offer.

Eric experienced the transition phase as very challenging and struggles to relate his mathematics lectures to other subjects, or to his workplace (“To date I haven’t seen too many points where I can say ‘ok, you can definitely need this’”) but he seems able to adapt to the new situation (“But of course from my point of view I may not yet be able to figure that out”... “Maybe that will come with time”)

**recording_F: “Frederic”**

| Computer science student, age 19, *Abitur, gymnasium* | |
|---|---|
| Secondary school certificate: | 3.0 (medium) |
| Mathematics grades: | very good (A-level course) |
| Mathematics attitude: | liked mathematics |
| Pre-test result: | 41.2 |
| Gain score: | 34.4 |
| Pre-course participation: | self-study |
| number of online test attempts: | 9 |
| Mathematics I: | 4.6 (failed after two attempts) |

*Summary:* Frederic attended a *gymnasium* and had advanced courses in mathematics and physics, with very good grades in mathematics. Which is why he decided to study computer science. He made this decision after he graduated from secondary school; he was able to find an employer quite quickly. Being used to excel in mathematics he was quite dissatisfied with his pre-test result. He had to forward his test results to his employer which he stated was “not much of a problem”. However, he tried very hard to achieve a better result in the post-test, and he appeared to be quite proud that he eventually did. He studied all ten learning modules (in the online version) and his number of test attempts was quite high (9) (“That was really A LOT of time. If you really do all problems, take all tests, then you’ll need half a week for each module, minimum. If you work on it every day”). He preferred the online modules and his strategy was to move through them from beginning to end, two per week.

Although being very focused and showing a strong effort, Frederic failed his exams in logic and mathematics. This situation is quite stressful for him and he repeatedly comes back to it during the interview.

He acknowledges that the pre-course learning contents were helpful for his first year of study (“Sine, cosine, were useful, geometry not that much, pi and stuff, and constants and how to use them” ... “ It’s important to understand every single step of the calculation so that you can understand everything easily during the lecture.”). He certainly misses secondary school, and mathematics that is about “doing problems” and about “applying mathematics, that is much more agreeable”

His favourite subjects are “maybe Java ... or quality management”. He finds it hard to relate the mathematics lectures to his other courses (apart from logic) or to his workplace. (“in mathematics, you have to take it as it is. They put these definitions in front of you and that’s that.”)

Frederic likes mathematics problems with practical relevance and has a strong dislike for mathematical proofs (“And then, these proofs, you always have to think about it, is this proof complete or not? ... And that was different at school. There everything was logical, working through the problems, because these were just normal problems. But doing proofs, that’s the big difference”)

Frederic has a strong performance orientation which characterises his approach to mathematics learning. He prefers to study alone and only joined a study group after having failed the logic exam.

He seems to be very diligent in his learning (he is the only student in the interview sample who did all ten learning modules, but at the same time seems to lack appropriate strategies to deal with his problems in logic and mathematics at university.

Frederic appears to need some assistance but is reluctant to acknowledge that there is a problem. He holds on to learning strategies that were successful at secondary school, like doing as many problems as possible.

**recording_J: "Julia"**

| Computer science student, age 20, vocational school and later *gymnasium* | |
|---|---|
| Secondary school certificate: | 1.9 (good) |
| Mathematics grades: | good (A-level course) |
| Mathematics attitude: | liked mathematics |
| Pre-test result: | 45.9 |
| Gain score: | 14.1 |
| Pre-course participation: | self-study |
| number of online test attempts: | 1 (learned with pdf files) |
| Mathematics I: | 3.0 (medium) |

*Summary:* Julia has attended a vocational school and later changed to a *gymnasium* where she graduated with a good *Abitur*. She decided to study computer science some years ago therefore already knew that mathematics would be important (she therefore took an advanced mathematics course at school).

She was informed via e-mail how to participate in the pre-test and pre-course. She learned by herself with the pdf-files. In the interview it emerged that she would have liked to study with the interactive material but did not find it / was not aware of it. She also was unaware of the additional e-tutoring and face-to-face courses and forgot which learning modules she worked through. At the same time she remembered some mathematical techniques from the pre-course she eventually needed in her first months at university ("Many pre-course contents were useful later and I thought 'oh, thank goodness I repeated that'"). During the interview she also referred to sine and cosine functions as important knowledge for her first year mathematics course.

During the study preparation phase she always learned alone. Today, it is a mixture of learning alone and in a study group ("Well, mostly I prefer studying on my own. But especially in maths I find it makes sense to study in groups. There will always be one person knowing something the others don't. And then the next person gets an idea the others would NEVER have. Yes, I really do think it helps."). Usually, the group of four or five students works through the theory / the script, and then they do the problems for themselves ("if someone has a question they will post it on Whatsapp, like, somebody's done this problem?")

Her favourite subjects are Java programming ("I always loved programming") and digital technology. The biggest difference between mathematics at school and university for her is the much faster pace and higher difficulty level. She also found it hard at first to understand the formal language. "In the beginning, I really had problems with mathematical language, like, x is element of a, and so on. We never did that at school, never."). She therefore suggests adding a section where this language and its use are explained step by step.

She does not always see relations between her mathematics lectures and her other subjects or the engineering profession, however, she tries to make sense by talking to her colleagues: “Because I asked around in my company a bit, or told them “Okay, we did this and this in maths. And this and this”, and then they said right away: “Sure, we did that, we know that, and sometimes we need it.” So, it still seems to be relevant. And if people have been out of university for 30 years and they still remember it, they obviously need it now and again, yes.”

Regarding workload Julia’s comments are somewhat contradictory. She states that their schedules are really full and that they have to learn a lot, but at the same time she claims that she usually does not learn on weekends, and only randomly on evenings (“I have a lot of leisure time. If you would use all this time for learning, you would walk out with a straight A”)

Julia’s approach to learning mathematics: do exercises if the theory appears to be a problem / was not understood, learn in groups, seek help, and do not forget to have fun. Her interest in understanding mathematics is mainly sparked by finding applications in programming, and at her workplace.

**recording_M: “Marc”**

| Mechanical engineering student, age 19, *Abitur, gymnasium* | |
|---|---|
| Secondary school certificate: | 1.8 (good) |
| Mathematics grades: | very good (attended additional mathematics course) |
| Mathematics attitude: | favourite subject |
| Pre-test result: | 42.4 |
| Gain score: | 28.8 |
| Pre-course participation: | e-tutoring |
| number of online test attempts: | 5 |
| Mathematics I: | 1.8 (good) |

*Summary:* Marc did two apprenticeships during secondary school and after that knew that he wanted to study mechanical engineering. He was always good at mathematics (“I was one of the best at my school in the final mathematics exam”) and thus wondered why he performed quite poorly in the pre-test. He was concerned but not too scared (“I thought, when I can’t make it others will struggle even more, therefore I thought ok maybe I have to invest some more time into this but it will probably be manageable to get good grades in the end”) As he had forgotten some contents from secondary school he was glad that he could focus on those issues in the pre-course.

He mainly had to “refresh” geometry and trigonometry and felt well prepared after having done so. He considers more or less all pre-course learning contents as relevant for his degree programme, “not only in mathematics, but in other subjects, as well”.

Unlike the computer science students, he does not have to do mathematical proofs at university (“at least not in exams”). He also thinks that the pre-course was maybe a bit too difficult compared to his lectures at university. (“on the other hand, it is difficult to say what you might need most afterwards, so it probably was ok and a good basis for the engineering course”).

He participated in the e-tutoring course which was ok ("sometimes, though, a face-to-face course might have been easier. Because, you read twenty pages and then you have forgotten where you started. I think, if there is a lecturer who presents it to you, and maybe shows how to solve a problem, then it's somewhat easier"). He studied four to five hours per week over a period of four weeks.

In the pre-course he mainly learned alone and thinks this was the most appropriate approach ("... and I've seen it happen that some use the study group to lean back and let the others do the work, and there won't be any effect"). He still prefers to learn alone but is also in touch with his fellow students who work for the same company.

In the pre-course, he liked word problems with relations to engineering. ("For example, the typical exercise with the acceleration of a vehicle, well, that is more fun than just calculating it on a piece of paper, instead you can imagine it visually and there is a connection to something real."). At university, he understands that his lecturers find it hard to relate mathematics to engineering "but when you have a topic and it comes back to you in different subjects, for example you have to compute the moment of inertia and you need a double integral, then you see the relations quite clearly".

The biggest difference to secondary school is that they practice less and learn not as deeply. "you have a topic in one week and then a completely different one the next week. It is much more compact and less elaborate, so you have to study alone a lot".

Marc's favourite subjects at university are mechanics and mathematics. His approach to learning mathematics is often strategic, he definitely wants to get good grades, but he also shows a strong interest in the application of mathematics and is able to relate it to engineering examples.

**recording_N: "Nora"**

| Mechanical engineering student, age 19, *Abitur, gymnasium* | |
|---|---|
| Secondary school certificate: | 1.9 (good) |
| Mathematics grades: | good |
| Mathematics attitude: | liked mathematics |
| Pre-test result: | 49.5 |
| Gain score: | 12.4 |
| Pre-course participation: | e-tutoring |
| number of online test attempts: | 4 |
| Mathematics I: | 1.3 (very good) |

*Summary:* Nora wanted to study at DHBW because she does not like too much theory ("it makes my brain hurt") but at the same time she was always good at mathematics and wanted to study something where she could use that. Her pre-test results did not worry her, she only stated to have some problems with trigonometry.

She focused on that topic in the pre-course but also did three other modules. She found the learning modules too easy at the beginning ("but I understand, there are people that lack the prior knowledge, they might need it that way") which is why she often only skimmed the text and focused on solving problems.

Nora prefers word problems ("otherwise it is just brainless calculations. In word problems you think about it and try to understand") but thinks a combination of different mathematics problems is best ("word problems also need much more time"). She dislikes mathematical proofs and is happy that they do not to do any in their exams ("I never know how to find the first approach ... and then you need time to play around with it")

She neither has a favourite subject at university nor dislikes a subject. Her grades are good and she seems to be quite self-confident. Application of mathematics knowledge she mainly finds in technical mechanics, but "the basics you need all the time, in all subjects". She also thinks that mathematics is very relevant for her job ("for me mathematics is mainly about logical thinking, that's what you need most ... it is not so much about computations but how to approach things, and that's what you need at the workplace, always")

## G.3 Categorisations

The interview analyses were carried out with *MAXQDA V12*. Categorisations were based on the sub-research questions but also on topics that emerged throughout the study.

| | Main code | subcode | description |
|---|---|---|---|
| 1 | Perceived relevance of pre-course | helpful / not helpful | Unexpectedly, students' statements about the perceived usefulness were positive only. They circled around different situations during their first months at university when they had been glad to have participated in the course. |
| 2 | Course curriculum | too broad / adequate / not broad enough | One student considered the pre-course syllabus as too broad, one stated it had not been broad enough. The other interviewees considered the syllabus as adequate. |
| 3 | Course curriculum | remembered / forgotten | Students were often unable to remember which topics they had worked through during the pre-course; remembered by students were trigonometry, polynomial long division, prime factorisation, logarithms, fractions, elimination of brackets, proofs |
| 4 | Personal experience | suggestions for first year students | Topics that were perceived relevant by students when asked to make suggestions for entering students: use of formal mathematical language, time management, invest more time, participate in forums |
| 5 | Pre-test self-reflection | performance-orientation / content-orientation | Students were different regarding their interpretation of test results, ranging from a high performance orientation in combination with being anxious to improve this result to a more relaxed content orientation |
| 6 | Time on task, effort | a lot / not much | Students were very diverse regarding the effort they had put into the pre-course, from 8 to 100 hours |
| 7 | Time management | does / does not use time management strategies | Most students were unable to describe how they planned their learning / did not or did not consciously make use of time management strategies |
| 8 | Real life application | likes real life problems / prefers proofs | Students were similar in their liking of "real" life applications. Some expressed that they disliked problems that took too long to understand / to answer. One student claimed to enjoy mathematical proofs over other types of problems. |
| 9 | Digital native | likes / dislikes e-learning; high / low level of technology based learning | Students were similar in their moderate use of learning technology in the pre-course and at university; the majority had enjoyed the web-based course and had learned online, one student had learned with the printed PDF files only (had not realised there was an interactive course, as well). Some reported to have searched the internet and YouTube for mathematics videos; some had shared solutions via WhatsApp. |
| 10 | First year experience | shock / no shock | Students' statements about the transition phase and the mathematics learning experience at university were quite similar; all claimed that the major difference to secondary school was a higher workload and a higher difficulty level. |
| 11 | Performance orientation during first year | performance orientation / no performance orientation | All students shared a relatively high performance orientation with a strong focus on grades. Most students stated to not have the time to pursue own interests, for example researching a topic they had found particularly interesting. |
| 12 | Use of learning strategies during first year | summarising lectures / doing problems / reading / library / Google / Youtube | Students' accounts about their use of mathematics learning strategies were similar in that they all summarised the lecture and did problems provided by their lecturers. They all used the internet (Google and YouTube) for their research. Only one student reported to study at the library and to search for additional information in books. |
| 13 | Learning how to | would / would | One student had participated in a course on learning how to learn |

| | | | |
|---|---|---|---|
| | learn | not like to participate in metacognitive training | at secondary school, the others had not. Two students stated that they would be interested in participating in such a course; three students stated they were not. All students were sceptical how to find the time for “yet another course” |
| 14 | Peer learning | likes study groups / dislikes study groups / finds it difficult to benefit from study groups / finds it difficult to find a study group | Students were very diverse regarding participation in study groups and in their description of the learning experience. Expressions ranged from high acceptance of learning in groups to preferring to study alone. Some students found it difficult to benefit from group work or considered it ineffective. One student would have liked to participate in a study group but found it difficult to build up the social contact to other students. |
| 15 | Help seeking | does need help and seeks help / does need help but does not seek help / does not need help and thus does not seek help | Students were also diverse regarding their need for help / support. Although four students had failed their first year mathematics exam they did not consider asking for support from lecturers or supervisors. By comparison, others used as much help as they could get, even though not being at risk to fail. |
| 16 | Relate knowledge | sees relevance of mathematics for technical applications and engineering / does not see relevance | Students were also different regarding their ability to relate knowledge, or find examples where mathematics was applied in other courses or at their workplace. Four students considered mathematics as highly relevant for all their courses (computer science and mechanical engineering) and sometimes for their workplace, as well. Two students found it very difficult to see the relevance of mathematics as it was taught at university for other subjects, or for then engineering domain. They seemed to miss their mathematics classes at secondary school. |