2018-12-21

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Journal of the Foundation Year Network

Journal of the Foundation Year Network, Volume 1 (2018), pp. 23-35

The "Mathematics Problem": A Plymouth Foundation Year Case Study

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Research indicates the transition from school mathematics to university-level STEM courses is often problematic, leading to issues with student satisfaction and retention (the "Mathematics Problem"). An increasing number of HEIs are establishing foundation years in an effort to ameliorate this problem. Undergraduate Mathematics cohorts at Plymouth often contain a sizeable number of ex-foundation year students, meaning that efforts to enhance student foundation year experience are vital to student satisfaction, retention and further recruitment. This paper is a report mid-way through a two-year project to examine a partially-flipped learning approach to improve foundation year retention and mathematical knowledge of those progressing to undergraduate study. A preliminary evaluation of this approach is given by using student voice data obtained through focus groups and surveys, and reflections of staff are examined. This paper is an expansion of the work presented at the Foundation Year Network Annual Conference, 2018, the overarching research question being: "Does the Foundation Year provide an enhanced transition to Mathematics degrees compared with the traditional A-level route?".

Introduction

The "Mathematics Problem" of mathematics students being ill-prepared by the school curriculum for university STEM-type study is well-known (LMS, 1995). The increasing number of universities offering a Foundation Year demonstrates that many students are leaving school without the required grades or subjects to enter the first year directly. The authors' experience of teaching on the first year of the Mathematics degree indicates that, even where students have met the entry qualifications, they sometimes remain unprepared for the rigour and work required to do well on at undergraduate level. The Mathematics Foundation Year (MFY) at the University of Plymouth has been running for many years under many guises. During that time there have been many changes in style of delivery, content and assessment, all with the aim of enhancing the student experience and thus providing a smooth but beneficial transition to the

first year of the Mathematics degree. This project will evaluate the current structure of the MFY to help ensure it does provide such a transition and, moreover, consider how it compares with the traditional A-level direct entry route onto the degree. This paper will review current literature on the topic, focusing on three areas that impact on the student experience and educational outcomes, namely student retention, student voice and flipped learning. The paper subsequently describes the project and presents the interim findings.

Literature Review

This literature review will survey some of the literature on the central topics for this project, namely the "Mathematics Problem" (focusing specifically on student retention), student voice and flipped learning.

The "Mathematics Problem" of mathematics students being ill-prepared by the school curriculum for university-level Mathematical-type study (which may include Engineering, Mathematics and other sciences) is well-known:

> Students … are hampered by a serious lack of essential technical facility. Compared with students in the early 1980s, there is a marked decline in students' analytical powers when faced with simple two-step or multi-step problems. Most students entering higher education no longer understand that mathematics is a precise discipline in which exact, reliable calculation, logical exposition and proof play essential roles; yet it is these features which make mathematics important. (London Mathematical Society [LMS], 1995)

While the LMS report specifically refers to UK HEIs, the Mathematics Problem seems to exist worldwide with numerous pieces of work pointing to this problem across many countries. Kajander et al. (2005) consider the actions of a Canadian university to overcome the problem by encouraging students to work before they enrol, using diagnostic testing and engaging in curriculum redesign. Luk (2005) exposes the gap from a Hong Kong perspective, covering issues relating to formal mathematical language and abstractness inherent in mathematics. Rylands et al. (2009) opine from the Australian point of view that "… a student's secondary school mathematics background, not their tertiary entrance score, has a dramatic effect on pass rates". Viewing school teachers and university lecturers as different groups, Hong et al. (2009) argue that, in New Zealand, "… each group lacks a clear understanding of the issues involved in the transition from the other's perspective". The above references indicate that retention of students is a challenge. The literature over time has evolved to consider student support mechanisms with Grove et al. (2017) reporting that mathematics support is widespread among UK HEIs and is strategically "… embedded as part of student-focused institutional support provision".

The phrase "student voice" refers to feedback from students, gathered from student surveys, evaluations, consultations and other such activities. The data generated should empower students by informing university processes relating to estates, teaching and other constituent parts of the student experience, although Rudduck et al. (2006) suggest institutions must respond effectively to ensure the student feedback results in genuine student inclusion. The work of Brooman et al. (2015) examines the role of the student voice in HE curriculum design and the value in responding to student voice: in this case, a statistical analysis was conducted showing a large increase in pass rates and a smaller, but appreciable, increase in average marks over a period of six years during which two curriculum redesigns were performed. Reasons suggested for this improvement included "a causal link between student involvement and better curriculum design for enhanced learning". However, interpretation of the student voice may be

a challenge dependent upon institutional structure and one's place in the institution (Freeman, 2016).

Flipped learning, according to the HE Academy, is:

> ...a pedagogical approach in which the conventional notion of classroom-based learning is inverted, so that students are introduced to the learning material before class, with classroom time then being used to deepen understanding through discussion with peers and problem-solving activities facilitated by teachers. (HE Academy, 2017)

Flipped learning is identified as having high impact in the medium term for UK HEIs (Sharples et al., 2014) via possibilities of improved learning and higher grades (HE Academy, 2017). Research indicates increased engagement with material (Mok, 2014); however, there are issues with resistance of students and staff to such a change in learning (White Baker et al., 2017). Indeed, some students may encounter issues with expectations concerning lecturer/student roles and having to do more work outside class hours (Wilson [2013] reports such issues from the trial of flipped learning in a statistics class). However, it does seem a promising approach for encouraging student engagement with material and the discursive approach allows the student to voice opinions and concerns that can be acted upon rapidly.

From the literature it can be seen there is a mathematics problem that impacts on student experience and retention, student voice is important and needs to be closely acted upon and flipped learning may serve as a method to ameliorate this problem. The project will aim to investigate these three aspects in relationship to the Foundation Year at Plymouth.

Foundation Years at Plymouth

Introduction

The Foundation Pathways in Technology at the University of Plymouth is a suite of six integrated Foundation Year programmes, each, subject to gaining a required aggregate mark and passing all modules, allowing entry to a range of programmes. Typically there are around 200-250 students on Foundation Pathways each year, enrolling onto a Mathematics, Computing or Engineering pathway. This paper concentrates on the Mathematics pathway (MFY). This pathway tends to attract 20-40 students each year. As with many Foundation Year programmes, MFY students may generally be classified into several entry groups. The number of such groups may be dependent upon location of the university, its ranking, subject and so on. At Plymouth two groups will be considered: 1) Students who failed to achieve the required A-level points for direct entry to the first year; 2) Students returning to study after a substantial break from education.

There is an ethical recruitment policy for MFY, with staff having considerable contact with applicants (building relationships) during the process. Many MFY students are also from under-represented groups such as mature students and care givers. Student retention, both during the MFY and progression into the first year, is important to the sustainability of the subject area in many HEIs.

Structure of the MFY

The year is split into two semesters with three modules in each semester as shown in Figure 1.

Semester 1	Computer Programming	Mathematics 1	Mechanics
	Tests + coursework	Weekly tests + exam	Coursework + exam
Semester 2	Investigations	Mathematics 2	Statistics
	Coursework + weekly tests	Weekly tests + exam	Coursework

Figure 1. The structure of the MFY at Plymouth. Cells shaded grey give the subject matter of the module with the unshaded cells directly below indicating the form of assessment.

Assessment is by several methods, including formal examinations. An innovative form of assessment, vivas (oral examinations), takes place in the 'Investigations' module. Vivas involve practising presentation skills using a whiteboard to provide answers in response to questions given typically a week beforehand, or in response to questions on a group project recently completed. The students also prepare videos explaining given topics. This form of assessment, also used on the Mathematics degree, is something a student from a typical A-level route seems unaccustomed to. Besides the modules, the students have an optional weekly PALS (peer assisted learning) session. These sessions are run by students in the second year of their Mathematics degree, usually students who have been on the MFY themselves. The group sizes for PALS sessions are 10-20 MFY students plus two PALS leaders. The aim of the PALS sessions is to allow the MFY students opportunities to ask about material covered in any modules they need help with.

The focus of the project is on the two Mathematics modules, where an enhanced co-teaching and cohort splitting approach is used. MFY students are co-taught with Engineering Foundation students for six hours per week, in addition to two hours of more intensive specific teaching and assessment. These Mathematics-specific classes are delivered by a partially-flipped learning approach designed to enable all students to be engaged in their learning at an accessible but challenging level. In Semester 2 the "degree" of flipped learning in Mathematics-specific sessions was increased, with the aim of moving from students being 'taught' as at school to 'learning' at university. Printed material was given to students one week, after which they were asked to work through it that week and attempt the exercises. In the following week's session students were encouraged to highlight items they did not understand and then these would be explained to the whole class.

The assessment for these two modules is in-class weekly tests which, in the first semester were short 10-15 minute tests. In Semester 2 the short tests were supplemented by two-hour investigative group assessments. Tests are usually based upon material given in the previous week's session. At the end of the test, the students are given the solution to compare to their own and are asked to give themselves an indicative mark for the work. They are encouraged to make a note of things they need to work on if they have made any errors. The tests are then marked by the tutor and the marked assessments with comments are returned to students in their PALS session (normally 1 or 2 days after the test). This approach attempts to instill an enhanced work ethic through regular assessment and fast formative feedback.

In addition to mathematical content, emphasis is placed on correctness and layout with these forming a crucial part of the assessment. In relation to the latter, there is an attempt to correct previously-taught approaches to mathematical grammar and syntax; in the authors' experience (for Mathematics students) students enroll with good calculational ability, but correct exposition and English is often a problem. Mathematical understanding lies in correct

exposition and English, and the approach attempts to correct this before they progress to first year. Finally, this approach is backed up by rigorous attendance monitoring and personal contact with students to enable early detection of students who may be at risk of low attendance or poor performance.

Methodology

A two-year study will be conducted starting with the 2017-18 intake and following them through the MFY and their first year of the Mathematics degree.

The research will be carried out using questionnaires and focus groups according to the schedule below. This will allow students to provide their views on the MFY, the material covered, the assessment style, their attitude towards being on the MFY and their views of mathematics.

- Year 1 of the study:
    - On entry, in September 2017, all MFY students were surveyed in relation to the topics above and to ascertain their route into the Foundation Year and their qualifications.
    - At the end of the first semester, all students were again surveyed to track changes in attitude and views since the previous survey.
    - At the beginning of the second semester, focus groups were held to allow the students to engage in more in-depth discussion. Questions were asked on material covered, teaching style, assessment, positives and negatives of the MFY, differences to previous education and their view of the suitability of the MFY as preparation for the full degree course.
    - At the end of the year a third questionnaire was administered to gauge students' reflections upon completing the year and how they thought it had prepared them for the first year.
- Year 2 of the study:
    - At the beginning of the first year on the degree programme, all students (direct entry and MFY entry) will be surveyed by questionnaire to ascertain their qualifications, how prepared they are to start a mathematics degree and their views of mathematics.
    - At the end of the first semester of the degree programme and again at the end of the year, all students will be surveyed by questionnaire to ascertain their views on the first year so far. Focus groups will be held to explore issues further.

There are 24 students in the 2017-18 cohort, labeled Student A - X, six of whom are female (Students D, F, J, G, H, S) and 18 male. There are five students (Students A, B, E, H, W) who are classified as students returning to study after a substantial break from education, four of whom lived locally to Plymouth prior to enrollment. One of these students withdrew at the beginning of Semester 2 due to family reasons. The remaining 19 students were students who failed to achieve the required A-level points for direct entry into the first year, four of whom attended a local school or college. One student was a Tier 4 student. The member of staff for the Mathematics-specific sessions as outlined above has extensive knowledge of mathematical education in both a university and school environment.

Findings from Questionnaires and Focus Groups

This paper reports on the project at the midway stage where the students have completed the Foundation Year and are about to embark on the first year of their degree. Some pertinent quotes from the questionnaires and focus groups are presented and commented on.

Questionnaire Findings

Questionnaire 1

Questionnaire 1 was administered on entry at the beginning of the second week of Semester 1. All students in the cohort were questioned on their route into the MFY, their qualifications, attitude towards the MFY and their views of mathematics.

A number of students were positive and looking forward to the year:

> "I feel comfortable starting the foundation course as it's the little step up I need from A-levels to help prepare me for year 1"; (Student F) "I am intrigued to explore the aspects of mathematics that I could not completely understand at A level"; (Student G) "Slightly disappointed that I didn't get straight onto the maths course but relieved that there was a safety net in place"; (Student L) "Excited/looking forward to the challenge + academic environment". (Student W).

The comment from Student L was reflected in comments from other students disappointed with their A-level results.

There were a significant number of students who expressed some anxiety towards starting the course, and particularly its content and pace:

> "Excited to learn more but worried that I will find it too difficult and everyone will be smarter than me"; (Student J) "Excited but also scared as it seems very fast paced and I am worried that if I don't understand something there won't be time to go over it again or to ask for help. But I am also very glad to be on the foundation course because it will prepare me for the degree" (Student S); "I feel it is daunting, hearing all of the work that is needed in such a short time, but positive that I can learn sufficiently as the facilities offered are extremely high quality and there is far more support, and easier to access than in secondary school or college". (Student X)

It is important for staff to be able to identify such students at an early stage. One of the advantages of having the Mathematics-specific sessions and the PALS sessions is to be able to identify students in this category, something that cannot always be done in a much larger group.

A few students were less than positive in their attitude at the beginning of the course:

> "So far it has been a little dull and simple, but I'm hoping it will pick up the pace fairly quickly. I'm slightly concerned that I might not be fast enough at learning the [Computer Programming]"; (Student K) "Jaded". (Student Q)

These were from students who had done relatively well at A Level Mathematics and had also taken Further Mathematics (A or AS level) but did not obtain the necessary tariff to meet first year entry requirements. Again, it is essential to monitor these students to ensure they do not remain 'jaded'.

Questionnaire 2

Questionnaire 2 was conducted at the end of Semester 1. Free text responses were used to ascertain their views on the MFY so far, material covered, teaching and assessment styles, their attitude towards being on the MFY and their views of mathematics.

Many comments reflected not only the hard work encouraged of the students but also that students seem to enjoy studying the material.

> "My knowledge has moved along massively since I started this course. Although it has been very past paced it's good because my knowledge and understanding has moved fast too". (Student B); "In the course so far we have covered a vast amount of material in mechanics and pure mathematics. My understanding of the subjects has improved and I feel I have improved especially in mechanics which I previously did not understand". (Student D)

Student G who stated that they did not fully understand some material at A Level now reports that:

> "It has given me an opportunity to solidify my understanding of the modules that I struggled with at A level and it has given me some time to adjust to the new teaching styles, timetables, lifestyle etc.". (Student G)

Comments on the teaching and learning style showed a range of responses that indicate the difference between University and school approaches:

> "I found that the teaching style was very different from school and feel that it was very beneficial for my understanding … The weekly tests also allowed me to consoladate [sic] my knowledge"; (Student D) "The teaching style is much better than I experienced at A-Level this has led me to want to learn much more than I did at A-Level". (Student N)

The students' views on the assessment were ascertained. It appears that, although the weekly tests were challenging for a variety of reasons, the overall impact was positive:

> "I felt like weekly assessments were a good way of making sure I was on track to understanding what I needed to improve but tests make me anxious and I don't think 15 mins is enough time to test someone's math ability"; (Student C) "[Assignments] handed back very quickly and done often enough that you can't slack off on the work ..."; (Student I) "The assessments took me slightly by surprise with their difficulty but it should lead me to study harder". (Student N)

A key part of the test marking was the emphasis placed on correctness and layout. Some students exhibited resistance to this:

> "Marking very strict compared to previous education but makes sense as to why and what is important to know. … Marks obtainable if work is put in"; (Student H) "I understand the need for marks on notation and layout but I believe it unfairly represented my maths ability"; (Student T) "The marking of these tests was often a little harsh". (Student Q)

Many students appreciated the Mathematics-specific sessions, with some commenting that they would like to have more such sessions:

> "I prefer being put in with just maths students rather than engineering as well as its less interactive however I understand the lecturer has to cater for all"; (Student F) "One major negative that I have experienced is being grouped in with the engineering students as I felt that most of the content was more generally aimed towards these students which is why it is nice to have sessions with just the mathematics students"; (Student G) "… more time for the [Mathematics-specific sessions] would have been appreciated, potentially another impact, as it was not enough time to cover everything we needed in enough depth". (Student J)

In an ideal world, it would be educationally sound to have every module as an MFY-only group, but the institutional discouragement of having small (< 50) cohort sizes makes this unviable in the current climate.

Some students were appreciating being on the MFY rather than going directly into the first year:

> "I have found this foundation course has proven that I would have struggled having gone straight into the first year and that the gap between college and uni was much greater than originally anticipated". (Student H)

Student Q who reported feeling 'jaded' at the beginning of the year now states:

> "It specifically prepares you for the real course unlike A level also by working in a university style as opposed to A level matches someone better prepared for the first year. The students are more independent than an A level course. Deeper explanations of topics & why they work the way they do. … I feel confident on some modules & less confident on others. I think this semester will be more challenging". (Student Q)

There was one comment from Student N that was perhaps the most telling, concerning the expectations of some students entering the MFY.

> "In the beginning I belived [sic] that the course was similar to a punishment for not reaching high grades but now I see it as an opportunity to gain experience and extra knowledge than someone coming into a degree straight from A level". (Student N)

Focus Groups

At the beginning of Semester 2, focus groups with a selection of students were held. There were three groups, each of five students. Focus Group 3 (FG3) consisted of the five 'returning students', with students in FG1 and FG2 randomly selected from the 19 remaining students. The rationale behind having a specific group for 'returners' was that they had different reasons for being on the Foundation Year. The focus groups were conducted as semi-structured interviews to expand upon the topics covered in Questionnaire 2.

When asked their general feelings about the course, FG1 felt the MFY had a "little bit more depth than what we are used to" and a "wide range of what it covers". FG3 felt the MFY gave the opportunity for "get[ting] things into place" before first year but indicated workload may be an issue when balancing studying and family commitments ("don't know how you would do this with a family"). Similarly, an FG2 participant opined that the MFY was "such a full-on course" with another participant saying "the Maths course is pretty intense".

As to material covered and the teaching approach, some FG1 students suggested weekly assessments were preferred while others seemed to prefer a single coursework assessment ("we need more time to go over it"). An FG2 member suggested the flipped approach was "trying to trip you up". FG3 suggested weekly Mathematics tests were stressful ("I've got to smash it

out in 15 minutes"). On the positive aspects of the MFY, FG1 opined that "it prepares you for university life … you look after yourself", contrasting the MFY environment with a school environment ("It's not a grade factory … you're a mathematician, not a grade"). However, members of FG2 indicated MFY students needed more MFY-only time, engaging in substantial discussion. On whether MFY prepares students well, some comments were:

> "So many people don't enjoy A levels … scrap A levels and just go straight for [Foundation Year]"; (FG1) "I don't think I could have gone on to the first year straight from A levels"; (FG2) "Having the Foundation Year has helped me out a lot because it has helped me to solidify everything because I didn't get it first time round"; (FG2) "Well ahead from where I was in September … given myself a much better chance". (FG3)

At the midpoint of the year it was clear that all students had received positive benefits from being on the MFY. There were, however, some students who were reluctant to accept the need for rigour in their written mathematics but the same standards were maintained in Semester 2. In Semester 2 the "degree" of the flipped classroom for the Mathematics-specific sessions was increased.

Questionnaire 3

At the end of the year a third questionnaire was administered to gauge students' reflection on completing the year and how they thought it had prepared them for the first year. Many comments suggested that students had good recollections of their past year:

> "I have learnt an awful lot and my knowledge of mathematics is a lot broader than it used to be"; (Student E) "It eases you into university and gives you a feel of independent study. It also helps with the understanding of maths as it gives you a base from which you can then build on in the first year in maths"; (Student F) "If you fail your A levels you can still do the course you wanted and it helps you adapt to uni life. … It's challenging but it's worth the challenge"; (Student M) "It has let me get onto a university course when I otherwise wouldn't be able to"; (Student N) "[P]repares you a lot for the amount of work you'll need to do and the kind of teaching method and assessments used"; (Student S) "[G]ave me time to learn things I didn't know". (Student V)

The need for rigour in their written mathematics appears to have had an impact as it was not commented on as a negative by any student. There were even some positive comments:

> "I feel I can now write [maths] correctly; (Student I) [S]mall mistakes or errors cannot be underestimated". (Student U)

However, it was apparent that there should have been more explanation of the rationale behind the flipped learning approach given to students.

> "Quite frustrating having to take work away to learn having never covered it before. Paying … to teach myself"; (Student B) "There's a lot of 'teach yourself' which I'm not particularly a fan of"; (Student L) "Don't like maths only sessions because we don't actually get taught". (Student S) "[The lecturer] handed out a sheet once a week and did no teaching". (Student W)

Nevertheless, some students appreciated the concept:

> "The teaching styles in this module was intriguing and enjoyable"; (Student G) "I appiciate [sic] the fact we were left to learn the content and would go over it in next lecture. Some people however struggled with this"; (Student R) "I prefer the smaller classes with more student input"; (Student T) "The idea of being given material … was a new concept which took time to adjust to, but once adjusted was effective way to learn". (Student X)

While the MFY hopefully prepares the student academically for the first year, students also confirmed it appears to prepare them well for University life in general.

> "Allows me adjust to university life at an easier pace than if I when [sic] straight into 1st year"; (Student O) "Preparation for … the style of learning at university"; (Student Q) "A year to familiarise myself with university life"; (Student R) "Prepares you a lot for the amount of work you'll need to do and the kind of teaching method and assessments used"; (Student S) "I know how the course is run and the campus layout"; (Student T) "I know more about whats [sic] coming next year to help me understand how uni works". (Student P)

At the end of the first half of this project it is pleasing to see how the students have engaged with this Foundation Year. When asked about the positives of the MFY in the final questionnaire, 71% of the students made (positive) reference to how the year had prepared them for progression to the first year. The above timeline of student comments illustrates the change in opinion of some students over the year, with many appreciating the differences between university and school environments even though they seemed to struggle initially with the flipped learning concept. The comments indicate that many of the students may have struggled had they been direct entrants to year 1.

Conclusions and Further Work

The second half of this project will take place over the year 2018-19 as detailed in the methodology. The number of students progressing from Foundation Year to the first year of the Mathematics degree will be compared to previous years. Comparing the attitude and progress of former MFY students with direct entrants will detect any differences in mathematical ability and learning attitudes compared to the remainder of the cohort. This will enable sharing of good practice with first year teaching staff to provide some way to mitigate the "Mathematics Problem", from a student-centered viewpoint, gaining a deeper understanding of the student experience and needs of diverse first year students. Based upon student observations and the authors' reflections, the following provisional findings are noted:

1. The MFY does provide a thorough grounding in Mathematics knowledge and rigour, as acknowledged by student comments.
2. The students are encouraged to work hard. This helps many students, but some still have trouble seeing the point at the end of the year.
3. Resistance to the teaching methods was apparent (common among flipped learning approaches, as in the literature review), but students reported effective learning.
4. An additional benefit to the students is that they seem to exhibit confidence in a university environment, and so can concentrate on the degree rather than the worry of being away from home for the first time.

5. Analysis of the focus groups indicates that younger students seem to struggle more with the flipped learning approach than non-traditional students (so flipped learning may need to be explained further to students).

These provisional findings will be explored and substantiated through the next part of the project.

Based on this evaluation of the year, changes to the MFY have been put into place for next year. There will be the addition of further longer assessments in the Semester 1 Mathematics module as students reacted favourably to those in Semester 2. The number of hours for the Mathematics-specific sessions will increase from two to three, again something the students requested. How to study at university, as opposed to being taught as at school, will be made more explicit from the beginning of the year. The flipped learning model will be explained in more depth and applied from the beginning of Semester 1. It seems that some students are better suited to the flipped learning model; this is something that can be explored further.

The comment from a student on MFY being seen as a punishment, although surprising, also deserves further exploration. It would be interesting to see if this opinion persists beyond the timeframe of this study and how widespread this opinion is among students.

Overall, the current model appeared to work well with the project cohort. It is anticipated it would maintain its efficacy in providing the same level of fast feedback and relationship between staff and individual students with a cohort size up to 40. However, if recruitment were increased, would this model provide the same benefits to a larger cohort size? What is the consequent impact on staff time and workload? Are further efficiency gains possible or desirable? Finally, through an increase of sharing good practice, it is hoped this work will impact the wider Foundation Year community, informing how Foundation Year curricula are devised and implemented.

Acknowledgments

The authors would like to thank the Centre for Mathematical Sciences, University of Plymouth for their generous hospitality. Thanks also go to Dr Suki Honey for her valuable advice and comments during writing and to the Foundation Year Network for their advice and organisation of the conference at which an earlier version of this work was presented. Finally, thanks goes to the anonymous reviewers of this article for their kind comments.

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