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Zafar, I

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Early-Career Scholarship

THE CLINICAL TEACHER ASME

RESEARCH ARTICLE

Exploring basic science knowledge retention within a cohort of undergraduate medical students in the United Kingdom: A longitudinal study

Idrees Zafar | John Chilton | James Edwards | Helen Watson | Daniel Zahra

Peninsula Medical School, Plymouth, UK

Correspondence
Idrees Zafar, Peninsula Medical School, Portland Square, Drake Circus, Plymouth PL4 8AA, UK.
Email: idrees.zafar@students.plymouth.ac.uk

Abstract

Background: Clinical reasoning is reliant on students having acquired a strong foundation in the basic sciences. However, there remains uncertainty regarding whether medical students are maintaining this knowledge over the span of their degrees. Therefore, this project aimed to assess long-term retention of basic science knowledge within a cohort of students from an undergraduate medical school in the United Kingdom (UK).

Methods: This longitudinal study followed a cohort of students, from their first to final year. In their final year, participants sat a bespoke formative basic science knowledge assessment that utilised 46 single-best-answer questions. To examine for long-term attainment differences, these scores were compared with those achieved in first-year assessments.

Results: Of the eligible students, 40% partook in the study ($n = 22$). Comparing assessment scores highlighted an enhancement in overall basic science knowledge between first and final year ($p < 0.01$). Although most basic science domains remained unchanged between both time points, anatomy and physiology scores increased ($p = 0.03$ and $p = 0.02$, respectively), whereas biochemistry scores were the only ones to decrease ($p = 0.02$).

Discussion: This project provides insight into how well students are retaining the basic sciences during their studies. Underperforming science domains were identified, alongside pedagogical explanations for their individual shortcomings; for instance, students' perceived relevance of a domain is seen as a driver for its retention. Subsequently, a group of recommendations were derived to reinforce the most affected domains. The inclusion of more questions on the underperforming sciences, in clinically focussed assessments, is one such suggestion.

1 | BACKGROUND

The landmark Flexner Report of 1910[1] has had long-lasting ramifications within global medical education. One such significant outcome was the increased emphasis placed on basic science training within medical curricula worldwide.[2] The original rationale was for students to gain an appreciation for the basic sciences, which would then be built upon by its clinical application. Subsequently,

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various curricula designs have emerged to address Flexner's recommendations.

The 'traditional' and 'integrated' medical curricula are examples of varied approaches that have been taken to incorporate basic science knowledge (BSK) within medical education. Although traditional curricula focus on a pre-clinical/clinical split, with basic science training occurring in the pre-clinical phase, integrated curricula allow for the sciences to be taught alongside clinical concepts.[3] Despite these innovations and developments in curricula design, concerns about how long students retain the basic sciences persist.[4,5]

Concerns about how long students retain the basic sciences persist.

Conflicting findings on the matter of BSK retention among medical students remains a recurring theme within the literature.[6,7] The transferability of these studies' findings to a UK population also remains unclear. Studies either focus on countries that solely have postgraduate medical students[8] or are limited to short-term retention intervals.[9]

This study set out to address these gaps in the literature, by examining long-term BSK retention within a cohort of undergraduate UK medical students. Representing the first UK study of its kind, and given the term 'basic sciences' and what constitutes them remains debatable, the study adheres to those subjects deemed to constitute the basic sciences in the UK General Medical Council's (GMC) 'Outcome for Graduates'.[10]

2 | METHODS

2.1 | Study design

A quantitative longitudinal study design was used to evaluate UK medical students' long-term BSK retention status. A cohort of final-year students' BSK scores were collated and compared with those achieved in their first year of studies.

2.2 | Study population

The sample was derived from a population of final-year students at a UK medical school ($N = 86$). Exclusion criteria were applied to ensure that only participants who had completed the same first and final-year BSK assessments were included in the study ($N = 55$). Those who had interrupted their studies for any reason, such as resitting or intercalating, were therefore excluded. Voluntary response sampling, with no additional incentives, was then utilised to determine the final sample size ($N = 22$).

2.3 | Data collection

Assessment scores and breakdown were used to obtain participants' BSK levels in their first and final years of medical school. Formative and summative End of Year 1 assessments were used to establish the first-year level and a Bespoke Formative Assessment for the final year.

2.3.1 | End of Year 1 assessments

The formative (fEoY1) and summative (sEoY1) End of Year 1 knowledge assessments were mapped to the GMC's 'Outcome for Graduates'.[10] The focus of these assessments was on 'professional knowledge', in particular biomedical scientific, psychological, social science and research scholarship principles.

Each assessment lasted 2.5 h and was composed of 100 single-best-answer questions. The questions were in the form of a vignette, and the students chose their answers from five listed options or by selecting the 'Don't Know' option. The assessments were negatively marked, with students scoring 1 mark for each correct response; dropping 0.25 marks for each incorrect response and 0 marks for each 'Don't Know' response.

2.3.2 | Bespoke Formative Assessment

The Bespoke Formative Assessment (BFA) was created, piloted and validated by institutional discipline leads who helped set up the EoY1 assessments. The BFA was mapped to aspects of the fEoY1 blueprint that the participants sat in their first year of studies. The BFA comprised of 46 single-best-answer questions, which were also negatively marked with the same penalties as the fEoY1 and sEoY1, and students chose their answers from four listed options or by selecting the 'Don't Know' option.

To accommodate for the BFA having fewer questions, only corresponding domains found within the fEoY1 and sEoY1 were included in the direct comparisons. This was done to keep domain variables the same when analysing the data. The domains included in the BFA, and the number of questions on each of these domains, are laid out in Table 1.

Because of the complexities in scheduling an in-person assessment, with final-year students being busy and COVID-19 affecting face-to-face activities, it was decided to make the BFA available on Microsoft Forms for 1 week. During this window of submission, only one response was allowed per participant and the assessment was limited to students within the institution. This was done to combat the potential sharing of questions between participants.

Replicating exact questions from either EoY1 assessments in the BFA was avoided, because of the possibility of students remembering answers. It was also decided to map the BFA to the fEoY1 test, instead of the sEoY1 test, because the BFA was thought to be more

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TABLE 1 GMC 'Outcome for Graduates' domain type and numbers found within the BFA.

BFA domains	Number of questions
Anatomy	8
Biochemistry	4
Cell Biology	2
Genetics	3
Immunology	6
Microbiology	3
Nutrition	2
Pathology	4
Physiology	8
Psychological Principles	1
Clinical Research and Scholarship	5

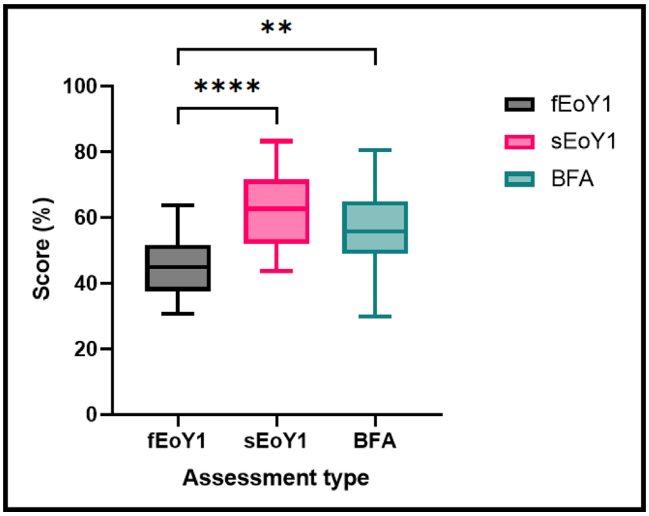

FIGURE 1 Box and whisker plots comparing the median and range of assessment scores across the different tests.
** = $p < 0.01$ and **** = $p < 0.0001$.

in line with a formative assessment. This conclusion was reached as the BFA would not count towards the student's progression in the medical degree programme, and the students were not expected to prepare for the BFA.

2.4 | Data analysis

Prior to data analysis, the Medical School's psychometrics team blinded the relevant assessment results and breakdown. Statistical analysis of data was then performed on GraphPad Prism version 9.3.1 (GraphPad Software Inc., USA). Analyses included descriptive statistics followed by normality testing, then inferential statistics. All data are stated as mean ± standard deviation with statistical significance taken as $p < 0.05$ unless otherwise stated.

The Shapiro–Wilk test was first used to analyse whether the data was normally distributed. With the dataset being normally distributed, parametric analysis of variance (ANOVA) inferential tests were used to assess for relationships between variables.[11] Specifically, a repeated measure one-way ANOVA and two-way ANOVAs with Tukey's multiple comparisons test were performed.

3 | RESULTS

The overall assessment scores of the 22 participating students are shown in Figure 1. Students scored higher in the sEoY1 (M = 62.10%, SD = 11.25), followed by the BFA (M = 55.83%, SD = 12.08) then the fEoY1 (M = 44.94%, SD = 9.57). The repeated measures one-way ANOVA with Tukey's multiple comparisons test revealed that there was a significant effect of assessment type on test scores $F(2, 21) = 19.24$, $p < 0.0001$. Noticeably students scored significantly higher in the BFA and sEoY1 than in the fEoY1.

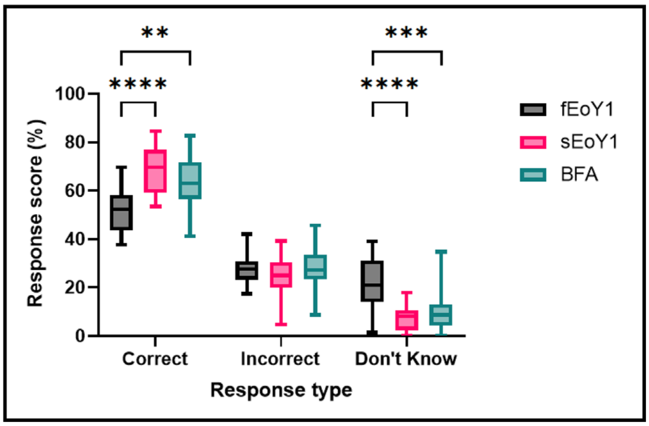

FIGURE 2 Box and whisker plots comparing the median and range of assessment responses across the different tests.
** = $p < 0.01$, *** = $p < 0.001$ and **** = $p < 0.0001$.

3.1 | Assessment responses

Figure 2 outlines the general trends in correct, incorrect and 'Don't Know' responses across the three tests. Students answered more correct responses in the sEoY1 (M = 68.13%, SD = 9.49), followed by the BFA (M = 62.75%, SD = 10.53) then the fEoY1 (M = 51.78%, SD = 9.52). However, there were more incorrect responses in the BFA (M = 27.67%, SD = 8.80), followed by the fEoY1 (M = 27.34%, SD = 5.89) then the sEoY1 (M = 24.46%, SD = 7.98). Finally, most 'Don't Know' responses were seen in the fEoY1 (M = 20.88%, SD = 11.41), followed by the BFA (M = 9.59%, SD = 8.21) then the sEoY1 (M = 7.41%, SD = 4.84). The two-way ANOVA with Tukey's

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multiple comparisons test revealed that there was a significant effect of assessment type on students' response types $F4, 126) = 25.72$, $p < 0.0001$. Noticeably, students answered a significantly higher proportion of correct answers, and fewer 'Don't Know' responses, in the BFA and sEoY1 than in the fEoY1.

3.2 | Domain scores

Figure 3 shows that scores across the basic science domains varied between assessments, with the two-way ANOVA with Tukey's multiple comparisons test revealing that there was a significant effect of assessment type on domain scores $F(20, 462) = 5.94$, $p < 0.0001$. Notably, in the BFA compared to the fEoY1 test, students scored significantly higher in the cell biology, anatomy and physiology domains and considerably lower in biochemistry.

3.3 | Domain responses

Figure 4 reveals that there were changes in response patterns across the tests, with the two-way ANOVA with Tukey's multiple comparisons test revealing that there was a significant effect of domain responses across the assessments $F(64, 1386) = 7.75$, $p < 0.0001$. Notably, there were fewer correct, more incorrect and the same 'Don't Know' responses in the biochemistry domain in the BFA compared with the fEoY1 test. Also, there were more correct, fewer incorrect and 'Don't Know' responses in the cell biology, anatomy and physiology domains in the BFA compared with the fEoY1.

4 | DISCUSSION

Though several studies have already assessed BSK retention in medical schools,[6–9] as far as we are aware, this is the first study to do so in the UK. Having followed the study participants' scores from their first to final year of medical school, the study examined an approximate 4-year knowledge retention interval. On average, the participants scored approximately 11% higher in the BFA than in the fEoY1. However, individual domain scores varied between assessments. Although students had gained knowledge in domains such as cell biology, anatomy and physiology, they had lost knowledge in others like biochemistry. These differences in findings could be related to a multitude of intertwining factors, some of which are outlined below.

4.1 | Domain exposure

Custers[5] suggests that differences in domain knowledge retention scores can be credited to the extent that a specific domain has been revisited and reinforced within a given retention interval. With overall content coverage and differences in students' abilities being something out of the control of educators, prolonged exposure to basic science domains remains the biggest governable driver for its long-term retention.[5,12]

This project found that final-year medical students' retention scores were either slightly increased or around the same across the BSK domains, except for biochemistry. Though it could be argued that biochemistry knowledge may not have been present in the first place,

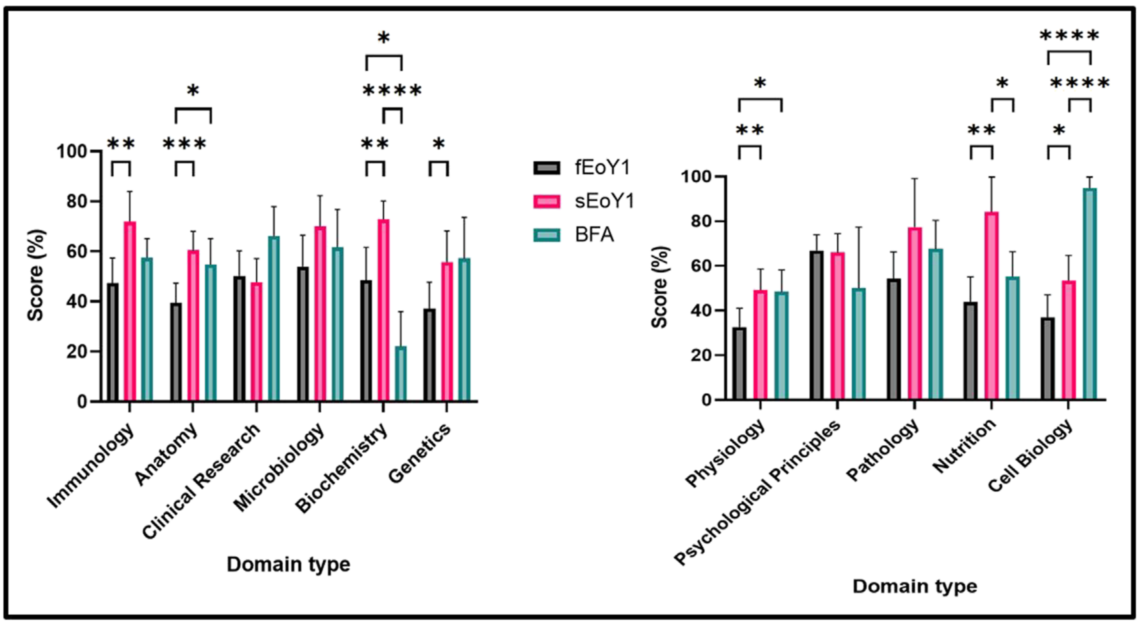

FIGURE 3 Bar chat plotted with 95% *CI* comparing domain scores across the different tests. $* = p < 0.05$, $** = p < 0.01$, $*** = p < 0.001$ and $**** = p < 0.0001$.

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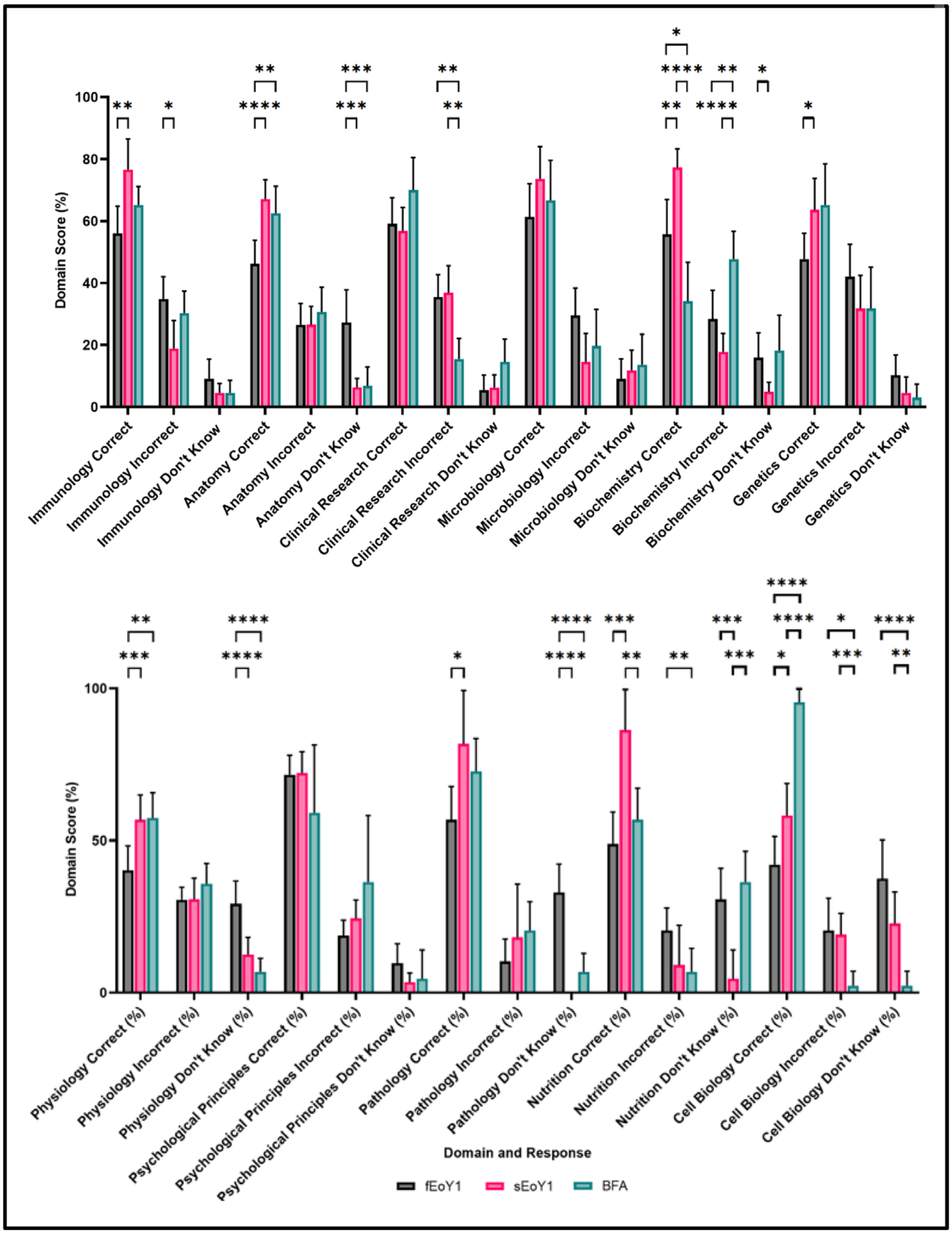

FIGURE 4 Bar chat plotted with 95% *CI* comparing the 11 different domains' responses across the different tests. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$ and **** = $p < 0.0001$.

or certain domains like anatomy may have always scored highly, the high biochemistry and low anatomy scores in both the fEoY1 and sEoY1 tests dismiss this theory in our context.

Retention scores were either slightly increased or around the same across the BSK domains, except for biochemistry.

Norris et al.[8] suggest that learning which occurs during clinical placements can provide further exposure and integration of BSK during the latter years of medical school. This factor can be seen as a potential cause of this project's observed effect on medical students' BSK retention. Biochemistry may not have been revisited and reinforced across the degree programme to the same extent as other BSK domains like cell biology, anatomy and physiology.

Our findings of senior medical students' loss in biochemistry knowledge, and gain in anatomy knowledge, are consistent with others that have reported the same.[6,13] Therefore, maybe more integration of biochemistry teaching in later years is required. However, Custers[5] suggests that simply incorporating extra integration, such as 1–2 h, of a specific domain is not likely to result in any detection of

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enhanced knowledge scores after a retention interval spanning 1+ years has elapsed. This reinforces the notion that the differing scores in the biochemistry and anatomy domain may not have been due to opportunistic teaching and learning encounters, rather the difference exists due to medical students being exposed considerably less or more to them.

4.2 | Perceived relevance

The premise that medical students need to thoroughly comprehend the basic sciences, to develop in-depth clinical knowledge, has been widely circulated in the field of medical education.[5] However, the prevalence of rote learning, in which students temporarily gain knowledge that they do not truly understand, shows that there is a mismatch between this ideology and students' current perceptions of the subject matter.[6] Extrapolating this concept to our project shows that there is a possibility that our findings, of varied knowledge retention scores across BSK domains, may be linked to students' attitudes towards the individual sciences.

Varied knowledge retention scores across BSK domains, may be linked to students' attitudes towards the individual sciences.

The longitudinal change in scores found among the anatomy and biochemistry domains may relate to general perceptions that medical students have towards them. The findings from other studies that corroborate ours, of an increased score in anatomy and reduced score in biochemistry, found that the underlying cause for this vast difference in knowledge retention may have something to do with students viewing anatomy as a more essential basic science and biochemistry as the least clinically relevant.[13,14]

These attitudes and beliefs may partly be intertwined with the 'domain exposure' factor, with there being a positive correlation between the number of clinical encounters with a particular domain and students' perceptions of its relevance.[6] With a perceived limited interaction with biochemistry, students may struggle to see the need to learn it. This links in with Knowles' theory of andragogy, which shows that adult learners must understand why they are required to learn a topic before they can embark on studying it.[15]

A possible solution may be the introduction of either a clinically orientated BSK assessment or if feasibility is a concern, the inclusion of more BSK questions in other clinically orientated assessments. The nature of the assessment being clinically orientated may help students visualise the significance of BSK in terms of clinical practice, helping them to invest more time into learning and retaining it.[8] This is in line with the constructivist learning theory, in which students base their learning on what they already know and can observe.[16] Also, assessment scores could have the additional benefit of assisting medical schools in establishing whether their curricula intended learning objectives are being met.[17]

A possible solution may be the introduction of either a clinically orientated BSK assessment or…

5 | STUDY LIMITATIONS

The participants that took part in our project may not have been representative of their original first-year cohort. Students from the original 2017/18 cohort that were pursuing an intercalated degree were excluded from the project because of not being in their final year of undergraduate medical studies during the 2021/22 academic year. The selection criteria for intercalation were based on academic attainment, and therefore, those intercalating could be perceived as being 'high attainers'.[18] Similarly, students from the original 2017/18 cohort that resat an academic year during the undergraduate programme were excluded from the project because of the same reason of not being in their final year of studies during the 2021/22 academic year. Though the reasons for re-sitting may not be linked to academic attainment, as the proportion of intercalators and re-sitters may not have been the same, a potential skew may have occurred in our participant recruitment process.

Furthermore, the number of questions on each BSK domain used within the BFA might have influenced our findings. With the number of questions on a given domain ranging from one to eight, a valid sample for reliable interpretation across the domains may not have been possible.[19] This means that the findings of knowledge retention scores between the domains in the BFA might have to be viewed with caution. However, the strength of the BFA being closely matched with the EoY1 tests meant that the ratio of questions per domain was similar across the different assessments. Therefore, the consistency of this factor means that it is less likely to have had an impact on the project's overall findings.

6 | CONCLUSION

The findings from this project revealed that BSK had been retained within a cohort of undergraduate medical students. However,

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irrespective of students' overall BSK retention, our findings show that individual basic science domain scores drastically varied. It is imperative that the issue of reduced domain knowledge retention rate is dealt with. Knowledge of all basic science domains is required to provide students with a sturdy foundation to build their clinical knowledge. Students' exposure and perceived relevance towards each basic science domain were deemed as potential contributory factors leading to our project's results. To overcome these factors, two viable solutions are suggested: further integrating less-retained basic science domains into clinical placements and incorporating more BSK questions into clinically orientated assessments.

To expand on the findings of this project, a multitude of future studies have been recommended. Most importantly, a qualitative study that provides the context behind this project's quantitative findings would be beneficial. Other suggested studies would be the analysis of BSK retention rates in other medical schools. The results from these such studies would help in identifying if any global patterns emerge.

To expand on the findings of this project, a multitude of future studies have been recommended.

ACKNOWLEDGEMENTS

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CONFLICT OF INTEREST STATEMENT

None.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT

Ethical approval was obtained from the University of Plymouth Faculty of Health Research Ethics and Integrity Committee. Project ID: 3215.

ORCID

Idrees Zafar https://orcid.org/0009-0004-7369-3378

James Edwards https://orcid.org/0000-0001-7114-5758

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