THE IMPORTANCE OF KEY PRE-REQUISITE MATHEMATICAL SKILLS FOR ENGINEERING SUBJECTS WITH HIGH TECHNICAL CONTENT

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Abstract

In the United Kingdom, the Teaching Excellence Framework (TEF) was introduced with the aims to enhance the quality of undergraduate teaching in UK higher education sector by assessing institutions on teaching standards, learning environments, and student outcomes. The emphasis is on student satisfaction and evaluation as to whether the educational experience provides value for money. There is a continuing shift from traditional teacher-centred learning to a more student-centred approach. Student-centred teaching and learning requires students to be active participants and encourages them to take more responsibility for their learning. Previous research explored the challenges facing educators required to teach subjects with high technical content in adopting a more student-centred approach rather than the traditional teacher-centred approach. Educators within the Engineering disciplines and other science-based areas were surveyed to ascertain their views on the potential challenges of using student-centred learning approaches in their teaching delivery. One of the key findings from this research is that a significant number of students entering higher education programmes in Engineering do not have the required key pre-requisite mathematical skills to cope with the material content within their programmes. A consequence of the lack of these key skills results in valuable time lost in class having to revise topics again prior to moving onto more advanced topics requiring these skills and making use of more innovative student-centre learning approaches. This paper considers the implications of the lack of the required pre-requisite mathematical skills for a module with very high technical content. The student feedback results indicate that it is crucial to have this key pre-requisite knowledge for the necessary self-confidence and better understanding of the new material being presented.

Keywords: Student-centred learning, high technical content, key pre-requisite skills, higher education.

1 INTRODUCTION

The UK higher education sector has undergone significant transformations aimed at enhancing teaching excellence, driven largely by policy reforms, student demands, and increasing competition in the global education market. One of the most pivotal changes was the full implementation and subsequent refinements of the Teaching Excellence Framework (TEF), introduced in 2017, which shifted focus from research dominance to teaching quality by assessing universities on criteria such as student engagement, teaching standards, and graduate outcomes.

Alongside the TEF, the Office for Students (OfS), established in 2018, became the new regulatory body replacing HEFCE and OFFA, with a mandate to ensure value for money, uphold teaching standards, and promote access and participation. The OfS introduced stricter accountability measures, including potential fines for institutions failing to meet quality thresholds, reflecting a growing government emphasis on transparency and student outcomes.

The student-as-consumer mindset has also intensified, with rising tuition fees also prompting demands for better teaching, enhanced support services, and career readiness. In response, universities have invested in digital learning platforms, personalised feedback systems, and student well-being initiatives. Engineering and science-based subjects tend to have modules with high technical content to deliver. Given the amount and high technical content of these modules, academics who are looking to adapt their delivery mode to become more student-centred may find this potentially challenging within the constraints of the programme in relation to required course content. Previous research in this area has highlighted many obstacles faced by educators who deliver subject material with high technical content [1]. A key finding from this research was that academics delivering modules with high technical content were encountering a significant proportion of their student cohorts who did not have the prerequisite key mathematical skills required for the subject matter being taught. This was leading to problems for educators requiring them to spend valuable time within the class to go over and revise key concepts and thereby restricting time available in the classroom for more student-centred learning approaches to be implemented. This research

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aims to evaluate the impact on student confidence levels and their understanding of new high technical material once they are taught and fully equipped with the basic key mathematical underlying concepts.

It is generally accepted that student-centred learning (SCL) approaches offer significant advantages over traditional teacher-centred learning (TCL) methods by fostering deeper engagement, critical thinking, and long-term knowledge retention. Unlike teacher-centred models, where instruction is largely lecture-based and passive, SCL prioritises active participation, collaboration, and personalised learning experiences tailored to individual student needs [2]. The main focus with SCL is more on the aspects of the students' learning and what students do to achieve this, rather than what the teacher is doing [3]. Another major benefit of SCL is its inclusivity and adaptability to diverse learning styles. By incorporating differentiated instruction, group work, and formative feedback, SCL accommodates varying paces and preferences, reducing disparities in achievement [4]. In contrast, teacher-centred approaches often adopt a "one-size-fits-all" delivery, disadvantaging students who require alternative methods to grasp concepts.

SCL also improves student satisfaction and retention rates. Research studies have linked active learning environments to lower dropout rates, as students feel more supported and invested in their education [5]. The emphasis on teacher-student interaction in SCL builds stronger mentorship relationships, addressing emotional and academic needs more effectively than impersonal lectures. Conversely, teacher-centred approaches risk disengagement, particularly among disadvantaged learners who may struggle with passive content absorption.

Also, Weimer (2013) emphasizes the importance of student-centred learning in higher education, highlighting five key aspects essential for its implementation [6]. First, the balance of power must shift from instructors to students, allowing them more control over their learning. Second, the content should focus on developing skills and understanding rather than just covering material. Third, the teacher's role transitions from information provider to facilitator of learning. Fourth, students should take responsibility for their learning through active engagement and self-regulation. Finally, assessment should be purposefully designed to promote learning, incorporating feedback and reflection. These elements collectively foster a more engaging and effective learning environment centred on student needs and growth.

It is understood that learning cannot be thought of either wholly student-centred or teacher-centred. In many practical scenarios especially teaching subjects with high technical content a combination of both approaches will be required. So, clearly implementation of student-centred learning approaches does not exclude completely using more traditional teaching approaches but makes use of pedagogic practices that are best suited for the particular required learning outcomes.

Educators particularly in the STEM subject areas who are required to teach material with high technical content find it more challenging to adopt a more student-centred approach compared to the traditional teacher-centred approach for various reasons [1]. One of major factors that causes educators problems is that a proportion of students now in Higher Education who do not enter university with the necessary pre-requisite skills. They may lack the necessary basic key mathematical skills required for their programmes of study. Academics cannot assume readily that all students in their classes can work on solving the more complex problems using student-centred learning approaches as on many occasions valuable class time is being lost in covering basic pre-requisite concepts. Another concern is that academics are being faced with situations where the students are not able or in many cases not willing to work as independent learners and so using active learning styles such as flipped classroom approaches become more challenging to implement in practice. Also, there are some problems around teaching very large cohorts of students and the difficulties this poses in ascertaining if effective learning is taking place for all students.

This present research focuses on first of these issues raised that of students who do not have the necessary basic key mathematical skills for their chosen engineering programmes. The research considers the impact of providing these basic key mathematical skills prior to studying new modules on the confidence level of students and their ultimate ability on better understanding the new material being studied.

2 METHODOLOGY

Students moving into their third year of study on Fire Engineering programme at University of Central Lancashire (UCLan) are required to study a module titled Probabilistic Risk Analysis. This module aims to develop mainstream engineering analysis techniques for engineering students. The emphasis is in application to probabilistic risk modelling for real-world processes. The module content relies heavily on pre-requisite mathematic skills developed and studied in years one and two of the programme. It was apparent that many of the cohort of students moving into the third year of study did not have a good understanding of these basic key mathematical concepts. This was due to either not fully understanding these complex concepts previously or having forgotten these concepts over time. The consequence of this was that their understanding of the high technical material content of their third-year module was proving very challenging for a large proportion of the cohort.

It was decided that a small cohort of nine students mainly full-time on campus students would be provided with extra mathematical support in terms of a one-hour session a week prior to their normal class delivery for the third-year module which was then delivered in block format approximately after every eight-weeks. This cohort were provided with revision sessions on the essential mathematical skills required in their next teaching block for their third-year module. Eight extra one-hour sessions were provided for this small cohort of students and their qualitative feedback was obtained at the end of this extra support sessions. Their final exam results were also considered and their scores were considered compared to the average for the whole class.

3 RESULTS

3.1 Questionnaire Feedback

The results from the questionnaires are represented by standard graphical bar charts and by using the mean and standard deviation for statistical analysis.

Question 1

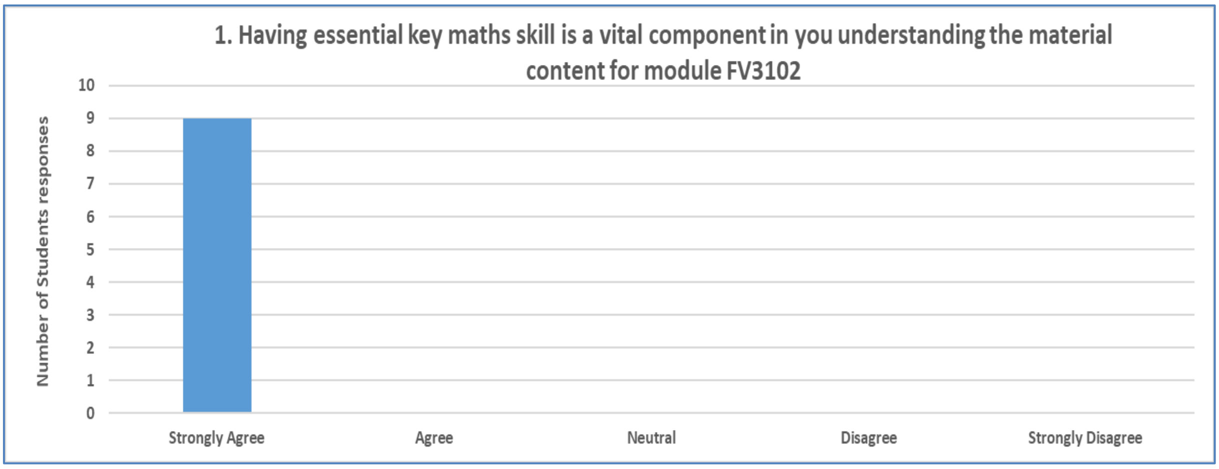

Figure 1. Is having essential key maths skills a vital component in you understanding the material content for module FV3102?

Question 2

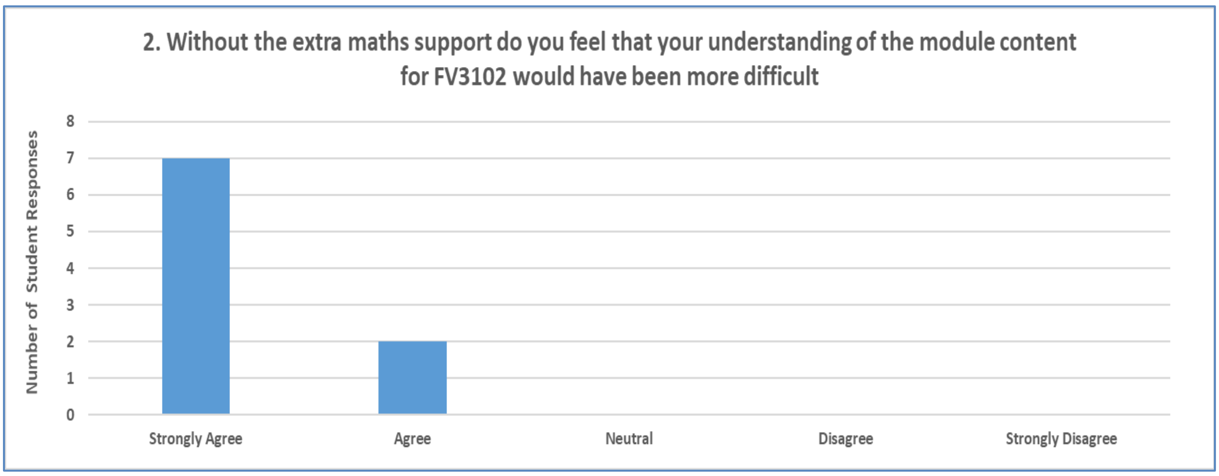

Figure 2. Without the extra maths support do you feel that your understanding of the module content for FV3102 would have been more difficult?

Question 3

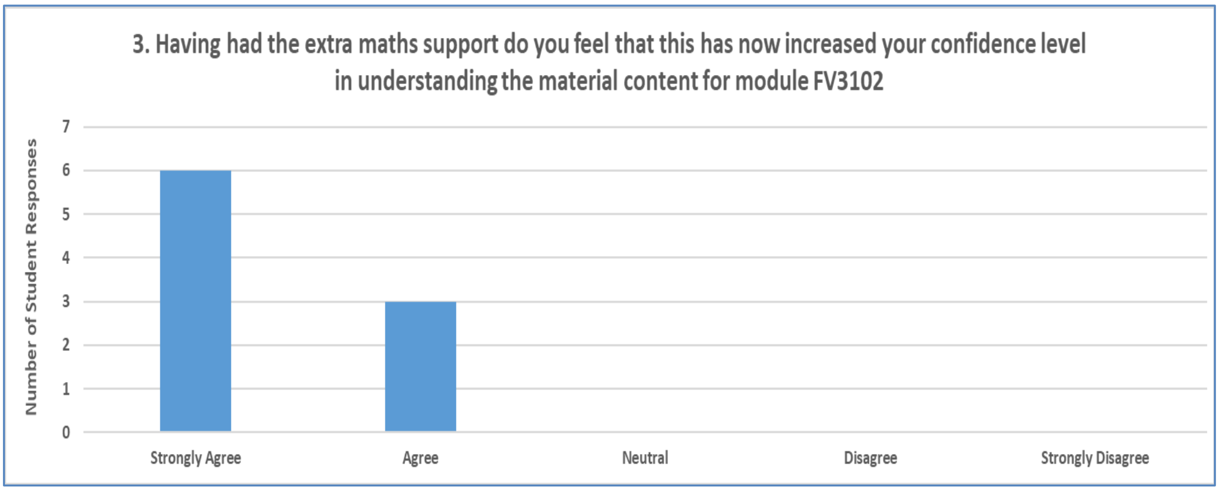

Figure 3. Having had the extra maths support, do you feel that this has now increased your confidence level in understanding the material content for module FV3102?

Question 4

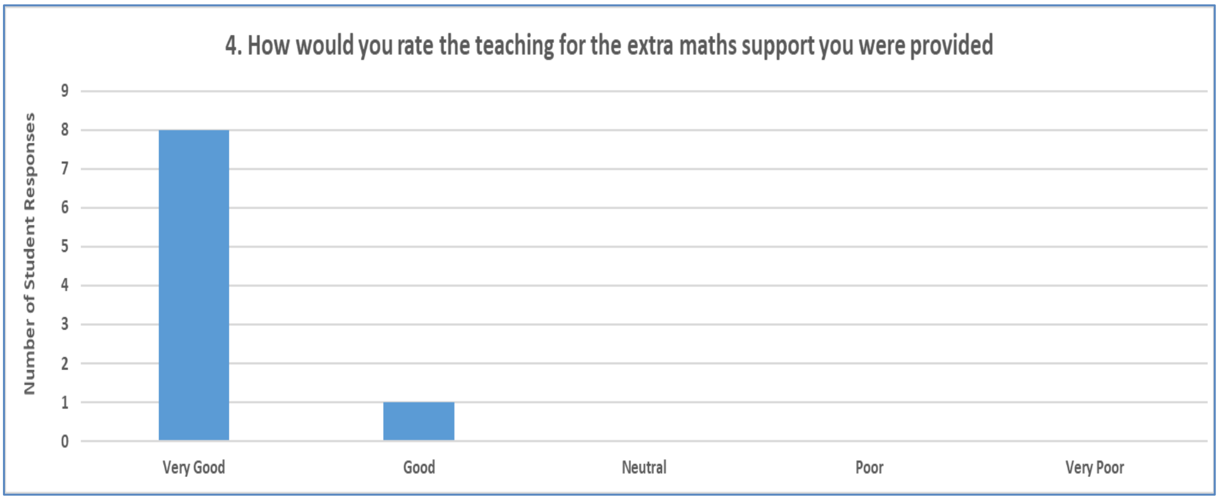

Figure 4. How would you rate the teaching for the extra maths support you were provided?

The qualitative responses above to the questionnaire do support our initial hypothesis that students will require key pre-requisite mathematical skills for subject material with high technical content. Question 1 shows 100%, i.e. all 9 students agreed that having these key maths skills are vital in their understanding of new material. Again, supporting this was the response for question 2 with 7 out 9 strongly agreeing and the other 2 agreeing that they would have found the new material difficult without the extra support. Question 3 shows that 6 out 9 strongly agree and the other three agree that their own confidence levels have increased and are now in a better position to tackling the new module subject material.

Question 4 was satisfying from a personal perspective that 8 out 9 students strongly agreed, and the other student also agreed that the teaching delivery of the extra maths support was of a high standard. Clearly, it was going to be important that this extra maths support was delivered in a way that the pre-requisite material was explained fully and in a manner that all students could understand it easily.

Table 1 below shows some further detail comments the nine students fed back in relation to the extra maths support provided to them.

Table 1. Student comments on extra maths support provide for module FV3102.

Student	Feedback Comments
1	"The additional support we have been provided is hugely beneficial in understanding the content better. For me, having complex topics broken into simple, systematic steps is essential to enable me to learn rules, interpret information and then build confidence in using these tools. Equally it is essential to have these foundation blocks laid out accurately and clearly, so I can access them again as I deconstruct the mistakes I, inevitably, make along the way. Thank you very much for the extra support".
2	"As a part-time student, my work commitments meant that I was not able to attend any of the tutorials live, either in person or on Teams. However, having now watched the recordings (more than once), this has proved invaluable - really appreciated, Khalid!"
3	"Having struggled with the pace and delivery in class, I have found the extra maths support very valuable to my learning process and has helped build my confidence at approaching the new topics covered. I am very grateful for the support Khalid has given; he has a way of delivering these complicated topics in a simpler, more understandable language for me to follow".
4.	"Thank you for the helpful and valuable extra classes".
5	"It has allowed me to not worry as much as I know issues related to the maths would be solved in these extra lessons and I appreciate that very much".
6	"The extra maths support has been extremely useful in terms of having the maths explained in a different way".
7	"The extra maths support has really helped me understand FV3102 better, improving my confidence and problem-solving skills".
8	"The maths support that I have received from Dr Khalid was very instrumental to me understanding probabilistic analysis, as I was struggling to understand this from the class lectures presented by the other lecturer".
9	"The excellent teaching offered has made a real difference to my understanding of the topics".

The comments from Table 1 show clearly that these students who have had the extra maths support prior to starting the new advance material all agreed that it definitely helped to increase their confidence levels when tackling the new subject material. Also, they indicate that their understanding of the new advance material became easier once they were comfortable with the key mathematical skills required.

3.2 Exam Results

The final examination result performances for these nine students who received extra maths support are shown in Table 2 below.

Table 2. Examination performance and difference from the mean score for the class.

Student	Examination Result (%)	Difference from the class mean $\overline{x}$ (62%)
1	90	+28
2	86	+24
3	85	+23
4	76	+14
5	71	+9
6	70	+8
7	55	-7%
8	44	-18%
9	43	-19%

It can be seen from Table 2 above that the six out nine students who received the extra maths support performed well above the class mean of 62%. That is two-thirds of students supported did perform better in the final examination than the overall class average. This again was a very positive outcome as students tend to find closed book examinations much more challenging than course work assignments and so again confirming what was reported in their qualitative feedback comments that the extra maths support did help with increasing their confidence levels and understanding of the subject matter.

4 CONCLUSIONS

In Conclusion, mastering essential prerequisite skills is critical for students before advancing to more advanced material, as these foundational abilities serve as the building blocks for higher-level learning. Without them, students may face unnecessary struggles, leading to frustration, poor academic performance, and persistent knowledge gaps. A strong foundation in prerequisite skills ensures smoother comprehension of advanced concepts. Additionally, possessing prerequisite skills boosts students' confidence, fostering a positive attitude toward learning and encouraging persistence when faced with challenging topics.

It was clear from the qualitative feedback received from the students who had the extra maths support that they found this as crucial in helping them to better understand their new advance material and also additionally increased their level of confidence in tackling the more challenging advance material. Also, as seen from the quantitative final exam results for the students who had the extra maths support, two-thirds i.e. 66.6% of this cohort had performed better than the class mean $\bar{x} = 62\%$. This again shows a positive gain in outcomes for these students who had the extra support.

Therefore, educators and learners alike must prioritise mastering prerequisites to facilitate effective knowledge acquisition, as overlooking them can lead to persistent difficulties. Investing time in building a strong foundation promotes long-term success in any discipline. Thus, prerequisite skills are not merely preliminary steps but essential components that determine a student's ability to thrive in advanced studies.

The question of how best to make sure that all students have the required pre-requisite skills for their programmes of study is something that could be incorporated within the timetable if time permits. Different models of teaching approaches i.e. "Block Delivery" of teaching may have the capacity to accommodate this better than others. Other alternatives could be by making use of time in the summer periods before the new academic year starts to run some extra sessions covering these basic key skills. A very positive approach would also be for module tutors to outline the key unpinning material that students will need in advance, to enable self-study prior to the start of the new academic year. However, this approach would be relying on students to be able to work as independent learners and this may unfortunately not prove as successful for many of the student cohort.

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