CHALLENGES IN HIGHER EDUCATION MATHEMATICS FOR ENGINEERING STUDENTS: A LITERATURE REVIEW

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Abstract: This paper presents a qualitative literature review on the difficulties faced by engineering students in higher education mathematics courses. The study discusses how insufficient mathematical preparation, weak study habits, limited conceptual understanding and difficulties with independent learning affect academic performance. It also highlights active learning, practical applications and academic support as strategies to improve student engagement and adjustment.

Keywords: Engineering education; mathematics education; higher education transition; student responsibility; applied learning.

INTRODUCTION

Mathematics is one of the most important subjects within engineering education because of its support to technical analysis, problem-solving and scientific reasoning. Engineering disciplines such as civil engineering, electrical engineering, chemical and mechanical engineering all rely heavily on mathematical concepts including calculus, trigonometry, statistics and differential equations (CABO; KLAASSEN, 2018). Without a strong mathematical foundation, engineering students often find it difficult to understand more advanced technical subjects.

In modern engineering environments, mathematics is also essential for technological innovation, computer simulations, data analysis and system optimization. Engineers frequently use mathematical models to design safer structures, improve electrical systems and solve environmental and industrial problems. Because of this, universities expect engineering students to possess both computational skills and analytical reasoning abilities (PEPIN et al., 2021).

Despite its importance, mathematics remains one of the most challenging subjects for many first-year engineering students. The adjustment from secondary education to higher education can be difficult because students suddenly have to experience a faster academic pace, increased independence and more complex methods of problem-solving (DI MARTINO; GREGORIO; IANNONE, 2023). Many students who performed well in secondary school, experience that university mathematics needs a deeper level of understanding and stronger analytical skills.

One of the main reasons students face these difficulties is that they are not sufficiently prepared in the basic mathematical topics required beforehand. Many incoming engineering students struggle with important mathematical skills as algebraic manipulation, trigonometric reasoning, graph interpretation and analytical thinking (PERANTE, 2022). Since engineering mathematics courses build upon previous knowledge, students who do not have a solid foundation in these areas, often find it difficult to understand more advanced topics such as calculus and differential equations.

Another reason is the difference between procedural learning and conceptual understanding. Procedural learning focuses mainly on memorizing formulas, following fixed steps, and repeatedly practicing similar types of exercises. Students who learn procedurally are often able to solve standard mathematical problems when the method and structure of the exercise are similar. This approach is commonly emphasized in secondary education because it may help students perform successfully during examinations and standardized tests (BERGSTEN; ENGELBRECHT; KAGESTEN, 2017). Conceptual understanding, however, involves a deeper comprehension of mathematical principles, relationships and reasoning processes. Students with strong conceptual understanding are generally able to explain why mathematical procedures work, interpret mathematical relationships and apply concepts flexibly in complex situations. Instead of depending only on memorized formulas, these students understand the underlying logic behind mathematical operations and are therefore better prepared to solve complex analytical problems. In many secondary

schools, students learn mathematics mainly by memorizing formulas and practicing similar types of exercises repeatedly. Although this approach may help students succeed in exams, it does not always develop a strong understanding of mathematical concepts. Because of this, students may struggle when they are required to apply mathematics to new or complex engineering problems (BERGSTEN; ENGELBRECHT; KAGESTEN, 2017).

Traditional lecture-based lectures can also make mathematics more difficult for engineering students. In some engineering programs, mathematics is taught in a highly theoretical manner without clearly demonstrating how the subjects relate to engineering practice. This may minimize the motivation of the student, because students often fail to recognize the practical value of mathematics within their future profession (PEPIN et al., 2021).

Another important challenge within modern engineering education is the increasing use of digital learning environments. Many universities now combine traditional classroom instruction with online learning platforms, recorded lectures and also virtual assignments. Although these technologies provide flexibility, some students experience difficulties maintaining concentration and discipline during independent online study sessions. Students who lack effective self-regulation skills may struggle to remain academically engaged outside the physical classroom environment (PEPIN et al., 2021).

Differences in educational background may also influence student performance in higher education mathematics courses. Students coming from schools with limited laboratory facilities, insufficient mathematics support, or fewer qualified teachers may enter university with weaker basic competencies compared to other students. These differences may contribute to educational inequality during the first year of engineering education (PERANTE, 2022).

Recent studies in education suggests that students often understand mathematics better when teaching is more interactive and connected to practical applications. Learning becomes more effective when students actively participate in discussions, collaborative problem-solving, laboratory exercises and practical engineering activities (STRELAN; OSBORN; PALMER, 2020).

Entering higher education also brings behavioral challenges. University students are expected to manage study schedules independently, complete assignments without continuous supervision and take responsibility for their own academic progress. Students who are used to more structured learning environments may find it difficult at first to adjust to independent learning, manage their time effectively and stay disciplined with their studies (DI MARTINO; GREGORIO; IANNONE, 2023). In addition, the shift from school to university often requires students to develop new study habits and adjustments to academic expectations. These adjustments may influence students' learning experiences and their overall performance in higher education.

Another important thing is, engineering students often experience stress and anxiety during the first academic year. The pressure to adjust quickly to university-level expectations, combined with difficult mathematics courses, may negatively affect their confidence and academic motivation. When students repeatedly struggle with mathematics, they may become discouraged and, in some cases, even lose interest in continuing their engineering studies (PERANTE, 2022).

For these reasons, many educational institutions have begun implementing innovative teaching methods, to help students adjust more effectively and enhance their performance in mathematics. Active learning strategies, contextualized instruction, collaborative learning environments and practical engineering activities have become increasingly relevant within engineering education (PEPIN et al., 2021).

This study was guided by the following research question: What are the main academic, behavioral and instructional factors that influence the difficulties faced by engineering students in higher education mathematics courses?

This paper analyzes the main difficulties faced by engineering students in higher education mathematics courses and explores how active learning strategies, practical applications and structured academic support can contribute to improved student adjusting and academic performance. In addition, the study highlights the importance of connecting mathematical concepts to real-world engineering problems in order to increase student motivation and participation. It also highlights the need for supportive learning environments that encourage participation, critical thinking, and collaborative problem-solving skills.

MATERIALS AND METHODS

This study applies a qualitative literature review methodology focused on engineering mathematics education within higher education institutions. A literature review approach was selected because it allows for the analysis and comparison of existing educational research related to the academic and behavioral difficulties experienced by engineering students during their transition into university mathematics courses.

Educational studies published after 2016 were selected according to their relevance to engineering student preparedness, conceptual understanding, active learning, academic adjustment, student

motivation and participation within higher education mathematics education. Recent literature was prioritized in order to examine contemporary educational trends, innovative teaching strategies and current challenges affecting first-year engineering students.

The analysis focused on several important aspects related to engineering mathematics education:

- mathematical preparedness among first-year engineering students;
- conceptual versus procedural understanding of mathematics;
- independent learning and student responsibility;
- active learning strategies in engineering education;
- practical engineering applications in mathematics instruction;
- collaborative learning environments and student participation;
- educational technology in mathematics education;
- academic adjustment during the transition to higher education.

Relevant peer-reviewed journal articles, conference papers and educational studies were carefully examined to identify common academic and behavioral challenges experienced by first-year engineering students. Particular attention was given to studies discussing the relationship between basic mathematical competencies and academic performance during the adjustment from secondary school to higher education learning environments.

The literature selection process focused primarily on studies related to engineering education, mathematics education and higher education learning methodologies. Studies discussing calculus readiness, analytical reasoning, conceptual understanding, mathematics anxiety, student motivation and active learning environments were considered especially relevant for this review. Educational research examining the influence of collaborative learning, project-based learning and application-oriented instruction on student participation and conceptual development was also included.

In addition, literature concerning collaborative learning environments, educational technology and engineering application-based instruction was examined to evaluate how these educational strategies influence conceptual understanding, analytical reasoning and student motivation. Special attention was given to educational studies discussing interactive learning environments, practical engineering activities and student-centered instructional approaches within mathematics education.

The reviewed literature was analyzed comparatively in order to identify recurring educational patterns, common academic difficulties and frequently recommended intervention strategies. Similarities between different educational studies were evaluated to determine which factors most strongly influence student adjustment and academic performance within engineering mathematics courses.

The qualitative nature of this study allows for a broader interpretation of educational experiences and instructional strategies related to engineering mathematics education. Rather than focusing on statistical analysis alone, this literature review emphasizes conceptual interpretation, educational trends, and the relationship between learning environments, student behavior, and academic performance within higher education engineering programs.

RESULTS AND DISCUSSION

The reviewed literature shows that the adjustment to higher education mathematics is not only an academic challenge, but also an emotional, behavioral, and social adjustment for many first-year engineering students (DI MARTINO; GREGORIO; IANNONE, 2023). Students entering engineering programs are often confronted with an educational environment that is different from secondary education. The increased academic workload, independent learning expectations and higher level of analytical reasoning required in university mathematics courses may initially create stress, uncertainty and frustration among students who are unfamiliar with higher education learning environments.

One of the most frequently discussed issues within the reviewed studies is mathematics anxiety. Many students enter university with negative perceptions about mathematics due to previous educational experiences or repeated difficulties experienced during secondary education. When students continuously struggle with mathematical exercises, they may gradually lose confidence in their academic abilities and begin doubting their capacity to succeed within engineering programs. This anxiety may negatively influence concentration, classroom participation, examination performance and overall academic motivation (PERANTE, 2022).

In addition to mathematics anxiety, some students experience difficulties adjusting to the communication style commonly used within university engineering programs. Lecturers often explain mathematical concepts more rapidly and expect students to interpret technical terminology independently. Students who are unfamiliar with academic mathematical language may require additional time to fully understand theoretical explanations and engineering-related

problem-solving procedures (DI MARTINO; GREGORIO; IANNONE, 2023).

Some students become reluctant to ask questions during lectures or tutorials because they fear making mistakes in front of classmates. As a result, misunderstandings and conceptual difficulties may remain unresolved for long periods of time, which may further weaken conceptual understanding and academic confidence. Educational researchers therefore highlight the importance of supportive classroom environments where students feel comfortable communicating openly, participating actively and learning from mistakes without fear of embarrassment or criticism (STRELAN; OSBORN; PALMER, 2020).

The reviewed studies also indicate that self-regulated learning skills strongly influence academic success within engineering mathematics courses. University students are expected to organize their study schedules independently, monitor academic progress, complete assignments responsibly and prepare for examinations without continuous supervision from teachers. Students who are able to manage their time and academic responsibilities effectively generally experience a smoother adjustment to higher education (DI MARTINO; GREGORIO; IANNONE, 2023).

In contrast, students with weak study habits and ineffective time management strategies often experience difficulties balancing lectures, assignments, laboratory work, project activities and examination preparation simultaneously. Many first-year students underestimate the amount of preparation required for university mathematics courses and therefore spend insufficient time practicing exercises or reviewing theoretical concepts. Ineffective study planning may result in incomplete assignments, increased academic pressure, weaker examination performance, and higher stress levels throughout the semester (DI MARTINO; GREGORIO; IANNONE, 2023).

Another important aspect discussed in the literature is how classroom interaction influences conceptual understanding. Traditional lecture-based teaching methods often focus heavily on theoretical explanation while students remain passive recipients of information. In such educational environments, students may become dependent on memorization and repetitive procedures rather than developing deeper analytical reasoning and conceptual understanding (BERGSTEN; ENGELBRECHT; KAGESTEN, 2017).

Active learning environments, however, encourage students to participate directly in discussions, collaborative exercises and mathematical problem-solving activities. By actively participating in discussions and problem-solving activities, students may develop stronger conceptual understanding and analytical reasoning skills. Research suggests that students who actively participate during mathematics instruction generally demonstrate stronger analytical reasoning skills and greater academic confidence (STRELAN; OSBORN; PALMER, 2020).

Collaborative learning environments also appear to positively influence student motivation and emotional adjustment during the first-year of engineering education. Through group discussions, teamwork activities and peer support systems, students are able to exchange ideas, compare analytical approaches and learn from one another's experiences. Collaborative educational environments may additionally reduce feelings of isolation and academic stress that many students experience during the transition into higher education (STRELAN; OSBORN; PALMER, 2020).

Peer interaction may additionally improve students' confidence and social adjustment during the transition into higher education. Students working together in study groups are often more willing to ask questions, explain concepts to one another, and discuss alternative analytical methods. Such collaborative experiences may strengthen both academic performance and interpersonal communication skills within engineering education (STRELAN; OSBORN; PALMER, 2020).

Project-based learning has also become increasingly important within engineering mathematics education because it helps students connect mathematical theory with practical engineering applications. Through engineering-related projects, students are exposed to realistic technical situations that require mathematical interpretation, analytical reasoning and problem-solving skills. Such activities encourage students to apply mathematical concepts actively while simultaneously developing professional engineering awareness and practical understanding (CABO; KLAASSEN, 2018).

Application-oriented instruction may further improve student motivation because students are more likely to appreciate mathematics when they recognize its practical value within engineering systems and technological innovation. Mathematical concepts often appear abstract when presented only theoretically. However, when concepts are connected directly to engineering examples such as electrical circuits, structural systems, thermodynamics, fluid mechanics, and mechanical design, students generally develop greater interest and engagement within the learning process (CABO; KLAASSEN, 2018).

The reviewed literature further highlights the growing importance of educational technology within modern engineering mathematics education. Interactive graphing software, virtual simulations, digital visualization tools and online learning platforms allow

students to explore mathematical concepts in more dynamic and interactive ways (PEPIN et al., 2021). Many students experience difficulties understanding abstract mathematical relationships when concepts are explained only through traditional lectures and static textbook examples.

Technology-supported learning environments may therefore improve conceptual understanding by helping students visualize functions, equations, graphs and engineering models more effectively. Online educational platforms also provide opportunities for repeated independent practice and immediate feedback, which may strengthen analytical reasoning and support continuous academic improvement outside the classroom environment (PEPIN et al., 2021).

The integration of educational technology within mathematics education also allows instructors to monitor student participation and progress more effectively. Online quizzes, interactive assignments and digital feedback systems may help identify conceptual difficulties at an earlier stage, allowing educational institutions to provide additional academic support before students experience serious learning problems (PEPIN et al., 2021).

The reviewed literature additionally suggests that preparatory mathematics interventions may significantly improve student readiness before entering advanced engineering mathematics courses. Bridging programs, orientation workshops and pre-calculus support sessions offered before the academic year begins may help students strengthen foundational competencies such as algebraic reasoning, trigonometry, graph interpretation, and analytical problem-solving (WONG; PAPAGEORGIOU; KLAASSEN, 2022). Such preparatory interventions may be particularly beneficial for students entering engineering programs from diverse educational backgrounds. By reviewing basic mathematical concepts before the beginning of the academic year, students may develop greater academic confidence and become more familiar with university-level expectations and problem-solving approaches. Students who begin engineering programs with stronger mathematical foundations are generally better prepared to understand advanced engineering concepts and technical applications.

Furthermore, educational researchers increasingly emphasize the importance of balancing procedural competency with conceptual understanding during mathematics instruction. Although procedural skills remain important for solving technical calculations accurately, conceptual understanding is essential for applying mathematics flexibly within unfamiliar engineering situations. Students who understand the reasoning behind mathematical procedures are generally more capable of adapting their knowledge to complex analytical tasks and engineering problem-solving activities (BERGSTEN; ENGELBRECHT; KAGESTEN, 2017).

In order to organize the main findings of the reviewed literature, the difficulties faced by engineering students in higher education mathematics courses were grouped into different categories. This categorization helps to demonstrate that student performance is influenced not only by previous mathematical knowledge, but also by cognitive, behavioral, emotional, institutional and instructional factors. Table 1 presents the main categories of difficulties identified in the literature.

Table 1. Main difficulties identified in engineering mathematics education.

Category	Main difficulty identified
Academic	Weak foundation in algebra, trigonometry, graph interpretation and basic calculus
Cognitive	Limited conceptual understanding and excessive dependence on memorized procedures
Behavioral	Poor study habits, weak time management and insufficient independent practice
Emotional	Mathematics anxiety, low confidence and fear of making mistakes
Institutional	Limited academic support, lack of preparatory courses and unequal educational backgrounds
Instructional	Excessively theoretical teaching and limited connection between mathematics and engineering practice

The categories presented in Table 1 show that difficulties in engineering mathematics education are multidimensional. Academic difficulties are often related to insufficient preparation in fundamental mathematical topics, while cognitive difficulties involve the inability to apply mathematical concepts flexibly in unfamiliar situations. Behavioral and emotional factors also play an important role, since students need discipline, confidence and independent learning skills to succeed in higher education. In addition, institutional and instructional factors may influence student performance when mathematics courses are not supported by adequate academic guidance or practical engineering applications.

Based on these difficulties, the reviewed literature also suggests several educational strategies that may contribute to improved student adjustment and academic performance. These strategies include preparatory mathematics support, active learning, collaborative tasks, practical engineering examples and the use of educational technology. Table 2 summarizes the relationship between the main difficulties and possible educational strategies.

Table 2. Difficulties and possible educational strategies.

Difficulty	Possible educational strategy
Insufficient mathematical preparation	Pre-calculus support sessions and bridging programs
Weak conceptual understanding	Conceptual explanations, visual representations and guided problem-solving
Low motivation	Use of real engineering examples and application-oriented activities
Poor study habits	Academic guidance, study planning and continuous monitoring
Mathematics anxiety	Supportive classroom environment and constructive feedback
Passive participation	Active learning, collaborative exercises and peer discussion
Difficulty with abstract concepts	Digital visualization tools, simulations and interactive platforms

The strategies presented in Table 2 indicate that improving student performance in engineering mathematics requires more than traditional lectures and repetitive exercises. Preparatory support can help students strengthen basic mathematical skills before entering advanced topics, while active and collaborative learning can increase participation and confidence. Application-oriented activities may also improve motivation by showing students the practical relevance of mathematics within engineering contexts. Therefore, an effective approach to engineering mathematics education should combine conceptual development, procedural practice, student responsibility and institutional support.

Student responsibility is an important factor in engineering mathematics education because success in higher education depends not only on institutional support and teaching strategies, but also on the active participation of students in their own learning process. In university mathematics courses, students are expected to study independently, complete assignments on time, review theoretical concepts regularly and practice mathematical exercises beyond classroom instruction.

The transition from secondary education to higher education requires students to develop greater autonomy, discipline and academic maturity. Unlike secondary school, where learning is often more structured and closely supervised, university education requires students to manage their own study schedules and take initiative when they experience difficulties. Students who do not ask questions, seek academic support or dedicate sufficient time to mathematical practice may experience greater difficulty understanding advanced engineering concepts.

Therefore, improving performance in engineering mathematics courses requires shared responsibility between students, lecturers and institutions. Lecturers should provide clear explanations, meaningful feedback and practical learning opportunities, while institutions should offer academic support and preparatory programs. At the same time, students must develop effective study habits, participate actively in learning activities and take responsibility for continuous improvement in their mathematical skills.

This study is limited to a qualitative literature review of selected studies related to engineering mathematics education, higher education transition and student academic adjustment. It does not include empirical data collected directly from engineering students, lecturers or higher education institutions. Therefore, the findings are based on the interpretation and comparison of existing literature rather than on surveys, interviews, classroom observations or statistical analysis.

Despite these limitations, the review provides an overview of important academic, behavioral, emotional and instructional factors that may influence student performance in engineering mathematics courses. Future research could include empirical investigations with first-year engineering students in specific institutional contexts in order to better understand their experiences, challenges and support needs.

Overall, the reviewed literature demonstrates that the mathematical difficulties experienced by engineering students are multidimensional and influenced by multiple interconnected academic, emotional, and behavioral factors. Academic preparedness, conceptual understanding, motivation, emotional adjustment, study behavior, classroom interaction and educational methodology all contribute significantly to student performance within higher education

mathematics courses. Educational institutions therefore play an essential role in creating supportive, interactive and application-oriented learning environments that encourage active participation, analytical reasoning, critical thinking and long-term academic development within engineering education.

CONCLUSION

Engineering students often experience difficulties during the adjustment from secondary education to higher education mathematics courses. These challenges are associated with insufficient mathematical preparation, limited conceptual understanding, weak study habits, mathematics anxiety and difficulties in adjusting to independent learning environments.

The literature reviewed in this study indicates that active learning strategies and application-oriented teaching methods can improve student participation, conceptual understanding and overall academic performance. Integrating practical engineering activities with foundational mathematics instruction helps students connect mathematical theory to real-world engineering applications.

The reviewed studies further demonstrate that successful adjustment to higher education mathematics requires more than technical knowledge alone. Students also require effective study strategies, self-discipline, time management skills and the ability to apply mathematical concepts flexibly within complex engineering contexts. Educational institutions therefore play an essential role in creating supportive and interactive learning environments.

The findings of this literature review suggest that improving engineering mathematics education requires cooperation between students, lecturers and educational institutions. While universities must provide supportive learning environments and effective instructional strategies, students must also actively participate in their own academic development through discipline, practice and continuous engagement with mathematical problem-solving activities (PEPIN et al., 2021). Future educational initiatives should continue focusing on contextualized engineering mathematics instruction, collaborative learning environments and active learning strategies in order to improve student motivation, conceptual understanding, and long-term academic achievement. Furthermore, the introduction of pre-calculus support sessions at the beginning of the academic year, particularly in September, may strengthen students' basic mathematical skills before entering advanced engineering mathematics courses. Such preparatory interventions may facilitate a smoother adjustment to higher education and contribute to improved academic performance among first-year engineering students.

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