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Mathematics teaching in engineering: methodologies and approaches

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ABSTRACT

Mathematics teaching in Engineering programs faces challenges such as connecting theory and practice and relying exclusively on lecture-based approaches. This Systematic Literature Review (SLR) aims to analyze and synthesize the existing literature on the different methodologies used to teach mathematical concepts in Engineering courses. Using the CAPES Portal of Journals and the SciELO Brazil database, the SLR includes 12 studies, primarily focused on Calculus teaching. Most of the methodologies employ technological resources. Students' difficulty in understanding mathematical concepts was identified as a limitation. This SLR seeks to contribute to the advancement of Mathematics teaching in Engineering by providing insights into the education of engineers.

KEYWORDS: Pedagogical approaches. Mathematics teaching. Engineering programs.

INTRODUCTION

Engineering has a significant relationship with basic disciplines such as Science and Mathematics (Roman Flores; Torres Silva, 2007). From the outset, Mathematics and Engineering have formed a partnership that has coexisted for the benefit and advancement of both fields (Giler-Velásquez, 2020). According to the author, Engineering provides the problems, while Mathematics provides the tools required to develop resources to solve them. Thus, this partnership stands out for proposing applications and providing instruments. In this regard, Giler-Velásquez (2020, p. 275) reiterates that “engineers must develop a set of specific skills, beginning with Mathematics.”

Therefore, the development of mathematical competencies in engineering education should consider social contexts that foster knowledge generation through the solution of problems arising from everyday activities (Giler-Velásquez, 2020). The author emphasizes that Mathematics teaching plays a crucial role in individuals’ overall cognitive development, requiring the assessment of fundamental cognitive activities such as reasoning, conceptualization, problem-solving, and reading comprehension. In other words, Engineering draws on Mathematics to model its applications, since Mathematics develops models with real-world applications that can solve or anticipate problems.

Mathematics can therefore be regarded as an essential component of the Engineering curriculum, while its collaboration with Engineering is crucial to developing innovative and efficient solutions in various technological and scientific fields. Despite challenges such as balancing theory and practice and adapting teaching to students’ different levels of preparation, Mathematics teaching in Engineering programs offers opportunities to integrate new technologies and pedagogical methods. In this context, this article explores the collaboration between these fields by addressing the following question*: What teaching methodologies have been employed to promote an understanding of mathematical concepts in Engineering courses, and how can they be applied to foster such understanding among students?*

To answer this question, a Systematic Literature Review (SLR) was conducted. According to Kitchenham (2004, p. 1), an SLR is described as a “means of identifying, evaluating, and interpreting all available research relevant to a particular research question, topic area, or phenomenon of interest.” According to the author, conducting an SLR is important for several reasons: it allows the existing evidence concerning a treatment or technology to be summarized, including the benefits and limitations of a specific agile method; it helps identify gaps in current research, suggesting areas for future studies; and it provides a framework or context that facilitates the appropriate positioning of new research activities.

Within this context, this article aims *to analyze and synthesize the existing literature on the different methodologies used to teach mathematical concepts in Engineering courses*. More specifically, it seeks to identify the most effective pedagogical approaches and provide support for educators and researchers interested in understanding how Mathematics has been taught in this field. To this end, a Systematic Literature Review (SLR) based on Kitchenham’s (2004) protocol was conducted, and its methodological details—including the PICOC strategy, inclusion and exclusion criteria, and the use of the StArt tool, are presented in the following section.

To compose the article's corpus, studies published between 2014 and 2023 were selected from the CAPES Portal of Journals and the SciELO Brazil database using the PICOC strategy, an approach employed to establish clear and specific criteria for including studies relevant to the analysis proposed in the SLR. The acronym was translated and adapted by the authors as follows: Population, Intervention, Comparison, Outcomes, and Context. The strategy was adapted from Kitchenham (2004), as shown in Chart 1.

Chart 1 – Criteria used in the PICOC strategy

Element	Characteristic
Population	Studies presenting Mathematics teaching methodologies employed in Engineering courses.
Intervention	Methodologies for teaching mathematical concepts applied in Engineering programs.
Comparison	Studies describing alternative or traditional Mathematics teaching methodologies published in journals in the field of Science and Mathematics Education.
Outcomes	Evidence concerning the effectiveness, limitations, and impacts of Mathematics teaching methodologies in Engineering courses.
Context	Studies focusing on Mathematics teaching in Engineering courses.

Source: The authors (2024).

The StArt (State of the Art through Systematic Review) application, developed by the Software Engineering Research Laboratory (LaPES) at the Federal University of São Carlos (UFSCar), was used to support the processing of the collected data. Fernandes (2013) describes StArt as a robust tool that stores reviews in an organized manner, focusing on the quality of the articles and studies gathered. The tool stores references, assigns scores, and filters studies that achieve an appropriate quality level for selection and use in the systematic review. It is worth noting that StArt is a tool that encompasses all stages of an SLR.

Considering the above, this SLR addresses the mathematics teaching methodologies used in Engineering courses within the established time frame. The database search was conducted in May 2024 and initially yielded 49 studies. Inclusion, exclusion, selection, extraction, and quality criteria were applied, culminating in the full-text review of 12 articles. The following protocol presents the criteria and stages of the SLR.

PROTOCOL

This SLR was conducted to analyze and synthesize the landscape of publications from 2014 to 2023 concerning the mathematics teaching methodologies that have been employed in Engineering courses. It sought to identify the pedagogical approaches implemented and their effectiveness, as well as to provide possibilities for educators and researchers interested in understanding how Mathematics is taught in this context. The protocol used in this study was based on Kitchenham (2004) and followed the review stages of planning, conducting, and reporting.

The SLR was planned by completing a protocol consisting of a detailed plan that guided the authors throughout all stages of the review process, ensuring that the research was conducted rigorously, transparently, and reproducibly. The protocol used the StArt tool as an organizational framework and considered the need to answer the article's guiding question.

The review was conducted by searching the databases to select primary studies with the following characteristics: peer-reviewed articles, which ensure the quality and credibility of the research and can help identify and correct potential errors, improve the clarity and accuracy of the results, and ensure that the study makes a meaningful contribution to scientific knowledge; open-access articles, which guarantee the availability of the studies; and articles reporting Brazilian experiences, a strategic choice intended to highlight and prioritize experiences relevant to the local context.

The search terms used in the selected databases were developed from the keywords "methodologies," "Mathematics teaching," and "Engineering field" and are presented in Chart 2, which also shows the initial number of studies retrieved.

Chart 2 – Search terms

Search terms	Database	Initial number
("methodologies" OR "pedagogical approaches" OR "teaching innovations" OR "teaching practices" OR "teaching strategies") AND ("higher education") AND ("Mathematics teaching" OR "Mathematics learning") AND ("Engineering" OR "Engineering field" OR "Engineering programs" OR "Engineering education" OR "Engineering students")	CAPES Portal of Journals	43
	SciELO Brazil Database	6
	TOTAL	49

Source: The authors (2024).

The initial number of studies (49 texts) was filtered using inclusion and exclusion criteria (Chart 3), making it possible to analyze and synthesize literature specifically addressing the topic of "Mathematics teaching methodologies in Engineering courses." Thus, some effective pedagogical approaches were identified, and this article seeks to provide insights for educators and researchers interested in understanding how Mathematics teaching has been carried out in the field of Engineering.

Chart 3 – Inclusion and exclusion criteria

Inclusion	Exclusion
Articles that directly address Mathematics teaching in Engineering programs or that describe and evaluate specific Mathematics teaching methodologies applied in Engineering contexts will be included.	Articles that do not fall within the scope of the research will be excluded, such as studies addressing the collaboration between Mathematics and fields other than Engineering or focusing on aspects unrelated to teaching methodologies (gender issues, dropout, historical aspects, textbook analysis, etc.).

Articles demonstrating the relevance and applicability of teaching methodologies in the context of Engineering education will be included.	Articles that do not directly address Mathematics teaching methodologies will be excluded, such as studies addressing methodologies in other fields of education or studies that are purely theoretical or of another nature (literature reviews, SLRs, etc.).
Articles presenting results concerning the effectiveness or impact of the proposed teaching methodologies will be included.	Articles that do not address local (Brazilian) experiences will be excluded.
Full-text articles will be included.	Duplicate articles will be excluded.

Source: The authors (2024).

Kitchenham (2004, p. 10) states that "study selection is a multistage process." The author initially recommends that the selection criteria be interpreted broadly so that, unless the studies identified electronically and manually can be clearly excluded based on their titles and abstracts, full-text copies should be obtained for a more detailed assessment. Following this recommendation and considering that the inclusion and exclusion criteria employed by the authors were based on the research question, the titles and abstracts were read to allow these criteria to be used for an initial screening. This process resulted in Chart 4, which presents the number of texts excluded at this stage and the corresponding reasons for their exclusion.

Chart 4 – Number of excluded studies and reasons for exclusion

Exclusion criterion	**Specification**	**Number**
Articles that do not fall within the scope of the research will be excluded, such as studies addressing the collaboration between Mathematics and fields other than Engineering or focusing on aspects unrelated to teaching methodologies (gender issues, dropout, historical aspects, textbook analysis, etc.).	Collaboration between Mathematics and a field other than Engineering	4
	Studies addressing aspects unrelated to teaching methodologies (gender issues, dropout, historical aspects, textbook analysis, curricular structure, etc.)	13
Articles that do not directly address Mathematics teaching methodologies will be excluded, such as studies addressing methodologies in other fields of education or studies that are purely theoretical or of another nature (literature reviews, SLRs, etc.).	Studies addressing methodologies in other fields of education	3
	Studies that are purely theoretical or of another nature (literature reviews, SLRs, etc.)	6
Articles that do not address local (Brazilian) experiences will be excluded.	-	4
Duplicate articles will be excluded.	-	6
TOTAL	-	36

Source: The authors (2024).

Following the exclusion stage, which resulted in the removal of 36 texts, 13 studies remained for analysis. However, when the reading process began, an ambiguity was identified in one of them: the journal's webpage indicated that it had been published in 2016, whereas the article itself and the corresponding issue indicated 2011, placing it outside the established time frame (2014–2023). In light of this inconsistency and in accordance with the principles of transparency and replicability underlying the SLR, the study was excluded, reducing the final corpus to 12 studies.

Chart 5 – Texts to be analyzed (included studies)

ID	Title	Author(s)	Year
E1	Dialogues in Mathematical Modeling	Ferruzzi; Almeida	2015
E2	Technology in Higher Education Teaching Practices: Graphmatica Software in Calculus Teaching	De Souza; Giongo	2016
E3	Between Theory and Practice: A Proposal for the Differential and Integral Calculus Learning Process in Civil Engineering	Guimarães	2019
E4	Engineering Students' Learning of Calculus Topics through Project Work	Magalhães	2019
E5	Using the Gapminder System to Support the Teaching of Linear Correlation Analysis in Higher Education	Frei	2020
E6	Teaching and Learning Differential and Integral Calculus through Problem-Solving in a Civil Engineering Program	Nunes *et al*.	2020
E7	Using Problem-Based Learning (PBL) as a Teaching Methodology in Numerical Calculus Classes	Blass; Irala	2020
E8	Augmented Reality and Area Measurement Calculations in Higher Education	Braga; Nunes	2021
E9	The Study of the Definite Integral through Interdisciplinary Problems Connecting Calculus and Physical Chemistry	Rachelli; Bolzan Denardi; Bisognin	2022
E10	The Use of Potentially Meaningful Digital Teaching and Learning Objects to Foster Creativity in the Exact Sciences	Neuenfeldt *et al*.	2022
E11	Critical Meaningful Learning in Mathematical Modeling Activities: Possibilities and Challenges	Lopes	2023
E12	STEM and Computational Thinking: Solving Real-Life Challenges in Higher Education	Costa; Martins; Domingos	2023

Source: The authors (2024).

Kitchenham (2004, p. 10) states that "in addition to general inclusion and exclusion criteria, it is generally considered important to assess the 'quality' of primary studies." According to the author, such an assessment enables more detailed criteria to be established for the studies. Furthermore, Kitchenham (2004) argues that it is necessary to investigate whether variations in study quality can explain differences in the results obtained. This also helps assess the relative importance of each study in the synthesis of results, guides the interpretation of the findings, and determines the strength of the inferences made, since well-defined criteria are considered essential for guiding recommendations for future research. Thus, the author emphasizes that "detailed quality assessments are generally based on 'quality instruments,' which are checklists of factors that need to be assessed for each study" (Kitchenham, 2004, p. 15).

Therefore, the quality assessment instrument adopted in this SLR emphasizes the following questions: Q1: Does the study focus on methodologies for teaching mathematical concepts in Engineering programs?; Q2: Does the study present a well-defined teaching methodology, with clear objectives, procedures, and data analysis?; Q3: Does the article include a robust discussion of the results, with critical analysis and contextualization within the field of study?; Q4: Does the research provide practical recommendations for educators and suggestions for future research in the field?; and Q5: Are the results presented in the article relevant to this research and do they contribute to understanding the Mathematics content addressed in Engineering programs?

The quality assessment conducted resulted in Chart 6. The fields were completed with "yes" (Y) or "no" (N) to indicate how the content of each study addresses the question posed.

Chart 6 – Quality assessment results

ID	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12
Q_1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q_2	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q_3	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q_4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Q_5	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Source: The authors (2024).

Thus, regarding the quality assessment, one of the studies did not provide affirmative answers to all the questions included in the quality assessment instrument. To record information concerning this study and the others, the authors extracted data to answer the questions raised more accurately. The extraction stage aims to "accurately record the information obtained by researchers from the primary studies" (Kitchenham, 2004, p. 17). In this regard, Chart 7 presents a comparative synthesis of the included studies, highlighting the main methodology addressed, the mathematical content, the study's main results and/or contributions, and the limitations identified.

Chart 7 – Comparative synthesis of the included studies

ID	Main methodology	Mathematical content	Main results/contributions	Limitations identified
E1	Mathematical Modeling	Calculus (rates of change)	Dialogues during the modeling process foster learning.	Limited methodological detail; insufficiently critical analysis.
E2	Use of Graphmatica software	Functions (Calculus I)	Technology improves understanding; teaching practices need to be reconsidered.	Students' difficulties with Algebra persisted.

E3	Problem-Based Learning (PBL)	Differential and Integral Calculus	Integration of theory and practice; student autonomy.	Initial resistance; requires more of the teacher's time.
E4	Project-Based Learning (PBL) with GeoGebra	Calculus (pendulum and piston)	Contextualized understanding; development of practical skills.	Lack of interdisciplinarity in one class.
E5	Gapminder system	Statistics (correlation)	Effective in consolidating introductory concepts.	Incomplete answers indicate partial understanding
E6	Teaching-Learning-Assessment through problem-solving	Differential and Integral Calculus	Students assume a leading role; teacher–student cooperation.	Students' insecurity; need for guidance.
E7	PBL in Numerical Calculus	Numerical Calculus	Increased interest; improved performance.	Large classes; adaptation to the format.
E8	Augmented Reality (AR)	Area measureme nt	Improved spatial perception and understanding of area.	Camera limitations; application design.
E9	Problem-solving (Pólya)	Definite integral	Deeper understanding; recognition of the importance of Mathematics in professional education.	Focus on isolated problems; lack of interdisciplinarity.
E10	Potentially Meaningful Digital Teaching and Learning Objects (PMDTLOs)	Mathemati cs topics	Integration of theory and practice; creativity.	Initial unfamiliarity; need for meaningful materials.
E11	Mathematical Modeling	Differential Equations	Critical meaningful learning; decentralization of teaching.	Error as a learning principle was insufficiently explored.
E12	STEM + Computational Thinking (Python)	Geometry, Algebra, and Calculus	Motivation; interdisciplinary perspective; perceived usefulness of Mathematics.	Difficulty with Python programming.

Source: The authors (2024).

The synthesis presented in Chart 7 highlights the diversity of methodologies and content, as well as recurring limitations, such as students' difficulties in understanding concepts and their resistance to innovative approaches. These aspects are discussed in greater depth below.

RESULTS

At this point, the authors consider it essential to revisit the initial research question – *What teaching methodologies have been employed to promote an understanding of mathematical concepts in Engineering courses, and how can they be applied to foster such understanding among students?* – as well as the study's general objective – *to analyze and synthesize the existing literature on the different methodologies used to teach mathematical concepts in Engineering courses.*

Thus, the SLR reaches its final stage. In the words of Kitchenham (2004, p. 22), "it is important to communicate the results of a systematic review effectively." Accordingly, the following data present the authors' reports and considerations regarding the data processing conducted in this SLR through the analysis of the studies previously listed. The results seek to answer the initial research question and, to this end, address the following points: (1) the mathematical content addressed; (2) the methodologies that have been employed to teach Mathematics in Engineering programs; (3) the limitations of the methodologies examined; and (4) recommendations for educators and higher education institutions based on the synthesis of the literature analyzed in the SLR.

From a quantitative perspective, 75% of the studies (9 out of 12) focus on the teaching of Differential and Integral Calculus, reflecting the emphasis placed on this subject in Engineering education. Regarding the methodologies, 58% (7 studies) employ some form of educational technology, 25% (3 studies) use problem- or project-based learning approaches (PBL), and 17% (2 studies) explore Mathematical Modeling. It should be noted that the studies are not homogeneous in terms of quality: although Study E1 was included, it did not meet two of the five quality criteria (Q2 and Q3), which may limit the robustness of its conclusions. The authors decided to retain it because of its thematic relevance, while explicitly considering its limitations in the analysis.

The compilation of the information highlights a common concern among the studies regarding the teaching of Differential and Integral Calculus to Engineering students. Chart 8 presents the list used to answer Q1.

Chart 8 – Mathematical content addressed in the studies

Mathematical content	**Related study/studies**
Differential and Integral Calculus (some studies address specific content, such as rates of change, functions, Calculus topics, and definite integrals)	E1, E2, E3, E4, E6, E9
Numerical Calculus	E7
Ordinary Differential Equations (ODEs)	E11
Statistics	E5
Area measurement	E8
Mathematics topics (Geometry, Algebra, Calculus, and Trigonometry)	E10, E12

Source: The authors (2024).

As mentioned at the beginning of this article, the mathematical content addressed in Engineering education is fundamental to the education of engineers. Most of the studies listed emphasize the teaching of Differential and Integral Calculus (E1, E2, E3, E4, E6, and E9). These studies explore methodologies such as the use of technological resources and problem- or project-based learning, while also providing practical contextualization, demonstrating that interactive tools and applicable examples significantly improve students' understanding and performance. In addition to Calculus, other important topics include Numerical Calculus (E7), Statistics (E5), Ordinary Differential Equations (E11), Area Measurement (E8), and general and advanced Mathematics topics (E10 and E12), each addressed through specific methodologies that emphasize practical application and the use of technology to enhance learning.

The emphasis placed on Calculus teaching in the studies may stem from the perception that this content is crucial to understanding and applying many fundamental concepts in Engineering. The abstract nature of Calculus can be challenging, requiring innovative methodologies to improve students' understanding and performance. Approaches such as problem-based learning, interactive technologies and graphical visualization tools, as well as methods that encourage collaboration and active learning, can make learning more intuitive and engaging, since Calculus is essential for modeling, analyzing, and solving complex problems that arise in various Engineering disciplines. Furthermore, proficiency in Calculus enables students to understand physical phenomena, perform simulations and predictions, and design efficient systems and processes.

Regarding the methodologies employed specifically for Mathematics teaching, whether in Calculus or in the other content areas mentioned in the studies, Chart 9 highlights these methodologies to answer Q2.

Chart 9 – Teaching methodologies addressed in the studies

Methodology	**Related study/studies**
Problem-Based Learning	E3, E7
Project-Based Learning	E4
Mathematics Teaching-Learning-Assessment through problem-solving	E6
Mathematical Modeling	E1, E11
George Pólya's problem-solving method	E9
Use of technology (specific software or system)	E2, E5, E8, E10, E12

Source: The authors (2024).

Problem-Based Learning (PBL), adopted in E3 and E7, has proven effective in connecting theory with real-world and everyday practices, making learning more dynamic and contextualized. Study E3 highlights the importance of giving students a voice, promoting autonomy and integrating theory and practice. E7, in turn, indicates that PBL increases interest and cooperation among students and teachers, although challenges related to time management and adaptation to the new format are also identified. According to the analysis of both studies, the successful implementation of PBL requires careful adjustments to time and classroom management, as well as continuous efforts to help students and teachers adapt to this approach.

The Mathematics Teaching-Learning-Assessment methodology through problem-solving, presented in E6, stands out as a collaborative approach involving teachers and students. When implemented continuously, the methodology enables students to assume responsibility for constructing their own knowledge when faced with a given problem. The authors of E6 draw on several researchers who advocate the importance of problem-solving in Mathematics learning, including George Pólya, whose method is employed in E9. This study adopted the principles outlined by Pólya to encourage students' autonomy in their learning and promote a more meaningful understanding of the knowledge constructed. By following the researcher's framework, E9 demonstrated that the method contributed to improving the teaching and learning of concepts. It also inferred that the method comprises fundamental stages for evaluating solutions and implementing possible corrections so that students can reach the correct solution to a problem.

The relevance of Mathematical Modeling is emphasized in E1 and E11. The authors of these studies identify it as a pedagogical approach capable of promoting meaningful and critical learning in Mathematics courses within Engineering programs. Study E1 focuses on the interactions and dialogues that occur during modeling activities. The researchers analyzed these interactions and observed that dialogue fosters student learning. E11 focuses on investigating critical meaningful learning in modeling activities and found that modeling supports principles such as reducing reliance on traditional teaching materials. Both studies emphasize the importance of Mathematical Modeling in fostering a more autonomous, reflective, and engaged approach to learning in the proposed field.

Although E4 addresses Project-Based Learning (PBL) as a teaching methodology, it combines this approach with technology through multidisciplinary projects. The study describes the simulation of the physical systems of a pendulum and an engine piston using GeoGebra software, followed by the physical construction of a prototype. The combination of PBL and technology is achieved through the practical and interdisciplinary application of mathematical concepts, promoting a contextualized understanding of the content while developing practical and collaborative skills.

Studies E2, E5, E8, E10, and E12 employ methodologies supported by technological tools to enhance the teaching strategies used for the content addressed. E2 discusses the integration of *Graphmatica* software, emphasizing the importance of examining its applicability to problem situations. The authors highlight the need to reconsider pedagogical practices in light of the challenges and opportunities introduced by technology. Study E5 explores the use of the *Gapminde*r system to teach statistical techniques, showing positive results in student learning and highlighting the effectiveness of this approach in constructing and consolidating introductory concepts. Study E8, in turn, presents a proposal for using Augmented Reality (AR) in teaching, demonstrating positive changes in students' perceptions and understanding after three-dimensional (3D) visualization.

E10 presents activities involving the production of videos as *Potentially Meaningful Digital Teaching and Learning Objects* (PMDTLOs), seeking an interactive and situated approach to Mathematics teaching. The study also sought to investigate different pedagogical approaches intended to facilitate the interactive development of content relevant to students, promoting a closer connection between theory and practice through creative expression.

Finally, E12 addresses the *CarRace* project, which promotes Computational Thinking within the context of STEM education. During the project's implementation, students were challenged to apply this type of thinking in a series of Mathematics-related activities using problem-solving strategies inspired by car racing games. The integration of Mathematics and *Python* programming is presented as a practical means of solving Engineering problems. This approach promotes an interdisciplinary perspective in which mathematical content is taught alongside programming, using real-world situations as a basis for learning.

In summary, studies E2, E5, E8, E10, and E12 highlight the methodological diversity of technology-based approaches and tools available for teaching Mathematics in Engineering courses, each with its own specific advantages and challenges. In this regard, the findings used to answer question Q3 of this SLR are presented below.

According to E3, the implementation of Problem-Based Learning (PBL) faces significant challenges, particularly regarding teacher and student engagement. For students, the main difficulty lies in transitioning from a passive to an active role, which requires greater collaboration and the development of new competencies and skills. Many students are accustomed to methods that favor the passive reception of knowledge. For teachers, the methodology requires more time and effort to teach the content and develop alternative practices. In addition to corroborating E3 regarding students' difficulty adapting to the new format and teachers' time-management challenges, Study E7 also addresses the issue of large classes. In this context, although the methodology makes classes more dynamic and improves student engagement, it still faces obstacles. In both studies, the authors provide a balanced perspective on the effectiveness of PBL in teaching mathematical concepts, suggesting areas for improvement in future implementations.

The limitations of Project-Based Learning (PBL) employed in E4 are specific to the context presented. The author highlights the advantages of using projects, particularly through an interdisciplinary approach. The limitation identified concerns the challenges faced by Mechanical Engineering students in coordinating the project, writing the final report, and orally presenting the results, since PBL was implemented with this class only within the Mathematics I course. In this case, the author observes that interdisciplinarity was absent; in other words, no other courses were involved to reinforce the cross-disciplinary aspects that are fundamental to the implementation of PBL.

Studies E6 and E9 address, respectively, Mathematics Teaching-Learning-Assessment through problem-solving and George Pólya's problem-solving method. Study E6 highlights students' insecurity when participating in an activity in which they were expected to assume a more active role. Furthermore, although the students demonstrated some knowledge of the content addressed, they required guidance to formalize their understanding. Although the authors of E9 identified advantages such as the methodology's contribution to concept comprehension and the importance of mathematical knowledge in understanding phenomena and theories related to professional education, they also highlighted a limitation of the study: the assessment focused exclusively on understanding and solving isolated problems, without incorporating interdisciplinarity. An interdisciplinary approach would have made it possible to assess students' learning of the concepts addressed in other problem situations.

Studies E2, E5, E8, E10, and E12 focus on the use of technology. Although E2 aims to address the possibilities and limitations of using the software, the authors do not explore its limitations in depth. The study emphasizes the positive impact of technology on students' learning processes and the need for teachers to adapt their pedagogical practices accordingly. The limitation mentioned concerns the algebraic analysis performed by the students – that is, their difficulty with the mathematical content – which had previously been observed in E6 and is also highlighted in E5. In this regard, E5 reports that some students provided inadequate or incomplete answers, indicating limitations in their understanding of the relationship between the data points and the correlation coefficient used. Despite the positive results observed in the study, this limitation suggests that challenges remain in assimilating the concepts through the *Gapminder* system.

Mathematical content was also highlighted in the teaching proposal employed in E8, which faced challenges related to students' initial perceptions of the content addressed – area calculation. When viewing a two-dimensional (2D) floor plan, students made statements that did not correspond to reality, indicating difficulty in accurately interpreting and applying geometric concepts without the assistance of Augmented Reality (AR) technology. Regarding the use of AR applications, cell phone cameras may also present and/or impose limitations. The authors designed the application with this limitation in mind.

Study E10 begins by acknowledging the recurring difficulties faced by students, such as negative experiences resulting from a lack of creativity in teaching approaches. Furthermore, the authors observed a certain degree of unfamiliarity among students with approaches that did not follow the traditional content-transmission format. Although the students included in the study were willing to participate in the activities, the authors considered this prior perception to be a relevant issue. It was also observed that, when exploring teaching strategies intended to overcome a possible separation between theory and practice in content development, relying solely on students' prior knowledge or willingness to learn is insufficient. Teachers must be capable of establishing a dialogical relationship between the two by developing potentially meaningful materials.

The study conducted in E12 was positively evaluated by most students, who emphasized the role of Mathematics and began to perceive it differently – as something useful. The limitation identified was that some students had difficulty mastering programming, particularly the *Python* language, which represented an additional challenge when completing the proposed tasks.

As previously noted, although the methodologies employed offer advantages, they also have several limitations, many of which relate to the mathematical content addressed. This finding corroborates the statements made by most authors regarding the significant challenges Engineering students face in mastering Mathematics content. The rapid progression of the curriculum in Engineering programs – students may begin with basic calculations and Algebra before advancing to Calculus I, Linear Algebra, Differential Equations, and other subjects, depending on their Engineering field – may hinder the consolidation of mathematical foundations, leading to conceptual gaps that can accumulate over time.

The lack of practical applications for the proposed mathematical concepts may also discourage students, who may question the relevance of such content to their future Engineering careers. Furthermore, the limited availability of teaching resources tailored to the specific needs of Engineering students may represent another obstacle, hindering the learning process and the development of the mathematical knowledge required for academic and professional success.

This is one of the reasons why the present SLR is important. The analysis concludes by presenting, in Chart 10, the recommendations addressed in Q4.

Chart 10 – Recommendations for educators and higher education institutions

ID	Recommendations based on the authors' conclusions
E1	Conduct similar studies with larger classes, involving a more representative number of students and, possibly, an external researcher to conduct the investigation.
E2	Conduct further research to explore the long-term impact of technology on teaching and learning processes in Mathematics education, considering the evolving nature of society and the role of technology in shaping educational practices.
E3	Encourage instructors from different disciplines to adopt the Problem-Based Learning (PBL) method.
E4	Implement an interdisciplinary approach to projects to increase their applicability, promote greater motivation, and avoid imposing additional tasks outside class hours.
E5	Adopt interactive systems supported by digital technologies, as they represent a significant advancement in Statistics learning.
E6	Use problem-solving methodologies continuously when teaching Mathematics in Engineering programs; create an environment conducive to cooperative and collaborative learning; investigate the impact of group work and collaboration in greater depth; and explore new problem-solving strategies and techniques.
E7	Focus on carefully preparing pre-class tasks, ensuring that the content addressed is effectively contextualized, in contrast to traditional exclusively lecture-based models.
E8	Develop proposals that broaden students' knowledge of the concept of area, including calculating area through integration and using AR to calculate areas involving curves, thereby providing a more interactive and in-depth learning experience.
E9	Integrate contextualized problems related to the subjects studied by students into Mathematics classes in Engineering and Science programs in general. Future research should investigate other mathematical concepts by comparing student performance in two groups: one using contextualized problem-solving and the other using traditional problems.
E10	Develop potentially meaningful materials that establish a dialogical relationship between theory and practice.
E11	Emphasize principles that receive less attention in Mathematical Modeling activities, such as learning through error. Future research should investigate ways to foster these principles and explore the relationship between critical meaningful learning and the mathematical difficulties faced by students.

E12	Implement STEM education, as this approach can improve academic performance, motivate students to learn Mathematics, and prepare them more effectively for future careers.

Source: The authors (2024).

In summary, it can be inferred that the authors recommend conducting studies with larger classes and involving external researchers to ensure more comprehensive and in-depth conclusions. They also emphasize the importance of adopting an interdisciplinary approach, using interactive systems, and continuously applying problem-solving methodologies in Engineering education. Furthermore, they highlight the need to prepare pre-class tasks carefully and include contextualized problems in Mathematics classes. Other recommendations include making teaching materials more meaningful, promoting learning through error, particularly in Mathematical Modeling, and implementing STEM education to improve the academic performance and professional preparation of students in the field.

The findings of this SLR are consistent with the international literature, which also indicates the predominance of Calculus as the focus of methodological innovations in Engineering education (Trigueros *et al.*, 2021; Bergsten; Engelbrecht; Kågesten, 2017). Studies such as Freeman et al. (2014) reinforce the effectiveness of active methodologies, including PBL and Project-Based Learning, in improving students' performance and motivation, corroborating the results observed in the articles analyzed. The use of digital technologies, such as visualization software and Augmented Reality, is also a global trend (Dede, 2009; Bower *et al.*, 2014), although challenges related to teacher education and infrastructure recur across different contexts.

It is equally important to acknowledge the limitations of this study. The exclusive focus on Brazilian databases – the CAPES Portal of Journals and SciELO Brazil – limits the scope of the results by excluding international experiences that could provide broader comparisons. Furthermore, although the time frame established in this study was appropriate for identifying recent trends, it may have excluded earlier seminal studies. The decision to include only peer-reviewed, open-access articles, while ensuring quality and availability, may have excluded relevant dissertations, theses, and conference proceedings. Finally, the methodological and quality-related heterogeneity of the primary studies, such as E1, requires caution when generalizing the results. Future reviews could expand the number of databases searched and include other types of publications to provide an even more comprehensive perspective.

FINAL CONSIDERATIONS

The proposal to conduct an SLR based on articles published between 2014 and 2023 in the CAPES Portal of Journals and the SciELO Brazil database made it possible to analyze the landscape of publications concerning Mathematics teaching methodologies employed in Engineering courses. This enabled the identification of the pedagogical approaches adopted, the assessment of their effectiveness, and the provision of insights for educators and researchers interested in understanding Mathematics teaching practices within this specific context.

By using these databases, the research drew attention to the number of scientific articles published in recognized journals, making it possible to analyze Mathematics teaching practices adopted by Brazilian Higher Education Institutions. Through this analysis, the different pedagogical approaches employed were identified, and their effectiveness in terms of student learning outcomes was assessed. Furthermore, the SLR identified gaps in knowledge and areas requiring further research and development. Although the number of articles was small, it proved relevant to answering the proposed research question.

The results presented offer possible pathways for educators and researchers interested in improving Mathematics teaching in Engineering courses. It is important to note that, although the SLR covered a ten-year period (2014-2023), research addressing Mathematics teaching methodologies in Engineering programs gained greater prominence during the final five years of the established period (2019-2023). This growth may have been encouraged by technological advances, including the widespread use of smartphones, as well as by teachers' concern with employing more effective methodologies for teaching Mathematics in Engineering programs.

The SLR is expected to have an impact on both the academic community and educators interested in exploring the proposed approach. Suggestions for developing new pedagogical approaches, integrating educational technologies into teaching, improving teacher education, and introducing changes to educational policies are among the potential contributions of this SLR, which highlights a relevant topic for the advancement and improvement of Mathematics teaching in Engineering.

The objective of this article – *to analyze and synthesize the existing literature on the different methodologies used to teach mathematical concepts in Engineering courses* – was considered to have been achieved. The identification of different pedagogical approaches, their effectiveness, and opportunities for further research by educators and researchers interested in understanding how Mathematics teaching has been conducted within Engineering courses also provide evidence that the intended objective was successfully accomplished.

It is expected that this research will provide an overview of the teaching practices currently employed and contribute to advances in understanding the mathematics teaching methodologies applied in Engineering programs. The limited number of studies addressing this topic represents a gap in knowledge, suggesting the need for further research to explore different approaches to Mathematics teaching in Engineering. The results and discussions presented in this study are expected to inspire new investigations in these areas, thereby contributing to more effective student education and academic development. Finally, conducting an SLR in the same field that also considers dissertations and theses is recommended.

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ENSINO DE MATEMÁTICA EM ENGENHARIA: METODOLOGIAS E ABORDAGENS

RESUMO

O ensino de Matemática em cursos de Engenharia enfrenta desafios como a conexão entre teoria e prática e o uso de abordagens exclusivamente expositivas. Esta Revisão Sistemática de Literatura (RSL) objetiva analisar e sintetizar a literatura existente sobre as diferentes metodologias de ensino dos conceitos matemáticos utilizados em disciplinas de cursos na área de engenharias. Utilizando o Portal de Periódicos da CAPES e a Biblioteca SciELO Brasil, a RSL inclui 12 estudos, principalmente focados no ensino de Cálculo. A maioria das metodologias emprega o uso de tecnologias. A dificuldade dos alunos em compreender conceitos matemáticos é uma limitação identificada. A RSL visa contribuir para o avanço do ensino de Matemática na área, oferecendo percepções para a formação de engenheiros.

PALAVRAS-CHAVE: Abordagens pedagógicas. Ensino de Matemática. Cursos de Engenharia.

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