Developing Critical Thinking Skills in Undergraduate Students: A Mapping Study in Computing Education

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Keywords: Computing Education, Critical Thinking Skills, Educational Strategies, Systematic Mapping Study.

Abstract: In the dynamic context of the digital age, academic training in information technology (IT) transcends the mere assimilation of theoretical knowledge, equally requiring the promotion of critical thinking among students. From this perspective, this research proposes a literary approach dedicated to investigating and analysing effective strategies for developing and stimulating critical thinking in IT students. In an environment where technology advances rapidly, it is crucial to equip future professionals in this field not only with solid technical knowledge but also with the intrinsic ability to critically analyse information and conceive innovative solutions in the face of emerging challenges. Thus, this study is motivated by the following research question: "How to develop critical thinking skills in IT undergraduate students?". To conduct this investigation, Kitchenham's systematic mapping studies method and the ChatGPT 4.0 version tool were used as instruments for formatting the extracted data, and visually, generating the charts and graphs. From 72 studies, the main highlighted results were observed, which reference the primary teaching methodologies and frameworks used, the benefits and limitations of these methods, as well as relevant information for understanding the courses in which these methods were applied, class sizes, course durations, and levels of education.

1 INTRODUCTION

In the current 21st-century landscape, characterized by rapid technological advancements, the development of critical thinking skills in information technology students has become a crucial necessity. This multifaceted skill enhances intellectual capacities and fosters multi perspective thinking, promoting the analytical and creative growth needed to solve complex problems and design innovative solutions (Gao, 2023; Prapulla et al., 2023).

In higher education, especially in the fields of Information Technology (IT) and engineering, critical thinking skills are imperative for students to transition from mere technical proficiency to holistic problem solvers. This skill set enables them to tackle complex issues by integrating diverse areas of knowledge, preparing them for challenges in the global market. For example, including liberal arts disciplines in technical curricula broadens students' perspectives, allowing them to explore various academic fields and develop interdisciplinary insights crucial for their professional and personal growth (Prapulla, et al., 2023).

Moreover, educators play a fundamental role in promoting critical thinking. They must go beyond traditional rote learning methods and adopt innovative and constructivist approaches that encourage active participation and inquiry by students. This shift not only enhances critical thinking but also aligns with the demands of modern educational systems that value creativity, communication, and collaboration (Raikou et al., 2017).

The development of critical thinking is closely linked to employability in the digital age. As work environments evolve, the ability to critically evaluate information and develop solutions becomes increasingly valuable. Studies suggest that interactive learning technologies significantly improve students' critical thinking skills, making them more adaptable and better prepared for the complexities of the modern job market (Gao, 2023).

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Mota, D. A. and Santos, S. C.
Developing Critical Thinking Skills in Undergraduate Students: A Mapping Study in Computing Education.
DOI: 10.5220/0013212100003932

In *Proceedings of the 17th International Conference on Computer Supported Education (CSEDU 2025) - Volume 2*, pages 481-492
ISBN: 978-989-758-746-7; ISSN: 2184-5026

Therefore, promoting critical thinking in educational contexts is vital for developing informed individuals capable of navigating the challenges of contemporary society. This requires a concerted effort to integrate critical thinking into various disciplines, employing innovative teaching methods, and creating learning environments that support the development of this essential skill set.

Motivated by these assumptions, the following research question was defined: RQ) "*How to develop critical thinking skills in IT undergraduate students?*"

So, through a mapping study of literature (MS), this study aims to investigate and analyse effective pedagogical strategies to develop and stimulate critical thinking in IT undergraduate students. With the accelerated advancement of technology, it is essential to equip future professionals not only with solid technical knowledge but also with the ability to critically analyse information and conceive innovative solutions (Prapulla et al., 2023; Beers, 2011).

This study is divided into five sections. After this brief introduction, Section 2 provides a detailed presentation of the definition of critical thinking over the years. Section 3 describes the methodology based on the systematic literature review method (Kitchenham & Charters, 2007), with focus on mapping study. Section 4 discusses the results, analyses the studies, and briefly presents the strategies in a guideline format. Finally, Section 5 presents the conclusion of this work and future remarks.

2 DEFINING CRITICAL THINKING OVER THE YEARS

Critical thinking is widely recognized as an essential skill involving the analysis, evaluation, and synthesis of information. Over the past twenty years, the definition of critical thinking has expanded to incorporate a variety of cognitive and dispositional skills. Facione (1990), described critical thinking as a self-regulated process of judgment that includes interpretation, analysis, evaluation, and inference, as well as the explanation of contextual and methodological evidence. This initial definition laid the groundwork for understanding critical thinking as a set of fundamental cognitive skills (Ennis, 1985).

In the following decade, Halpern (1998), added an important dimension by emphasizing the disposition to think critically. According to her, critical thinking is not limited to technical skills but also involves a predisposition to question, ponder, and reflect on issues in a rational and open-minded manner. This perspective was complemented by Paul and Elder (2004), who highlighted the importance of critical attitudes such as curiosity and skepticism in developing these skills.

In the 2010s, definitions of critical thinking began to incorporate the practical application of these skills in specific contexts. Davies (2015), suggested that critical thinking is a multidimensional process that combines cognitive skills with disciplinary knowledge, allowing for deeper and more contextualized analysis. He highlighted skills such as the ability to identify arguments, evaluate evidence, and develop coherent reasoning. Complementing this view, Abrami et al. (2015), emphasized the importance of integrating critical thinking into the academic curriculum in a practical and applied manner.

More recently, research has focused on specific skills associated with critical thinking. Alcaraz and Aguilar (2020), identified skills such as problem-solving, argument analysis, and the ability to make inferences as central to critical thinking. Additionally, Huber and Kuncel (2016), discussed the importance of metacognitive skills, such as self-reflection and the recognition of biases, in the practice of critical thinking. Lai (2011) also highlighted the need for teaching strategies that promote these skills in educational environments.

Thus, over the past twenty years, critical thinking has come to be understood not only as a set of technical skills but as a comprehensive competence that involves the disposition to think rationally, specific cognitive skills, and the ability to apply these skills in practical and disciplinary contexts.

3 RESEARCH METHOD

3.1 Systematic Mapping Studies

This study adopts the Systematic Mapping Studies method proposed by Kitchenham and Charters (2007). Systematic Mapping Studies (MS), or Scoping Studies, are a kind of literature review that aims to give a broad overview of a research field. They help determine whether research evidence is available on a specific topic and offer insights into the volume of that evidence. This current MS aims identifying, analysing, and interpreting all relevant research available that discusses strategies to improve the critical thinking skills of IT students, as well as the methods, impacts, and limitations.

The process is structured to provide a comprehensive understanding of the topic, helping to identify gaps in the existing knowledge and suggesting directions for future research.

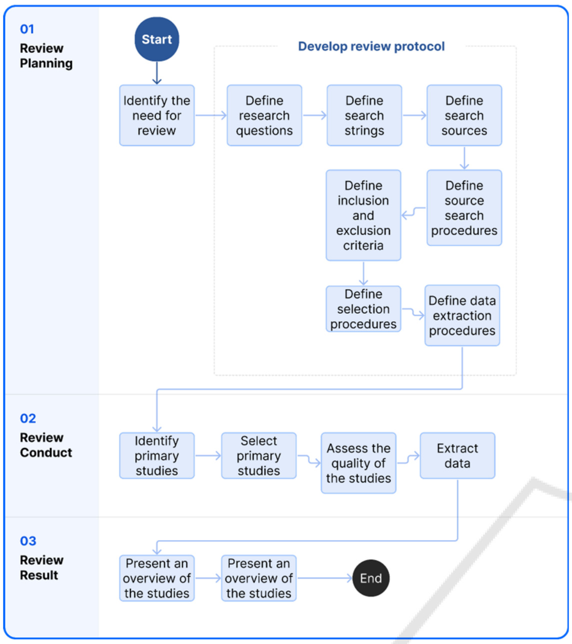

Figure 1: Review Protocol Flow. Source: Adapted from Kitchenham & Charters, 2007.

3.2 Review Planning

In the initial phase of the study, the review planning systematized the foundation upon which our investigation is built. This stage is crucial for establishing a clear and objective methodological framework, ensuring that the research is focused and relevant. During the planning, the central research questions that will guide our analysis were defined, as well as the inclusion and exclusion criteria that will ensure a rigorous and relevant selection of literature. This meticulous process aims to minimize bias and maximize the coverage of the review, providing a solid basis for the systematic collection of relevant data.

The central research question of this study is: "*How to develop critical thinking skills in IT undergraduate students?*"

The secondary questions include:

SQ1: *What is the context of the study regarding the development of critical thinking, considering: 1) educational level (undergraduate, postgraduate, continuing education, technical education), 2) courses (Information Technology and related fields), 3) class size, and 4) duration?*

SQ2: *What model, method, strategy, technique or approach is used to promote critical thinking?*

SQ3: *What are the main results achieved using this method?*

SQ4: *What are the perceived benefits in developing critical thinking?*

SQ5: *What challenges were encountered?*

The search string used combines the following keywords and synonyms to capture the widest possible range of relevant studies:

"Critical Thinking teach" OR "Critical Thinking teaching" OR "Critical Thinking skill" OR "Critical Thinking ability") AND (classroom OR education OR university OR college) AND (model OR method OR strateg OR technique OR approach)

It is essential to highlight that the context of this research considered higher education students, hence the choice of the terms "university" and "college".

3.3 Conducting the Review

After establishing a meticulous review plan, the review conduction phase is where the active search for knowledge is carried out. In this phase, the previously defined search strategies are employed to find studies that align with the research questions, applying inclusion and exclusion criteria to filter the relevant literature. This process involves the detailed selection of studies, extraction of essential data, and assessment of the quality of the included studies. It is a stage that demands rigor and precision, as this is where the volume of literature is refined until only the most pertinent and high-quality contributions are retained for further analysis.

The research knowledge basis were chosen based on their relevance and importance in the technology and innovation community. They are IEEE Xplore, Scopus, and ACM. The results of the selection process are shown in Table 1.

The inclusion and exclusion criteria are established to ensure the quality and relevance of the studies analysed. Excluded publications are those not within the 2014 to 2024 range (considering studies in last decade), duplicates or similar studies, unavailable for download or viewing, in languages other than English, less than 4 pages or more than 30 pages, already identified as SLR/MS (secondary studies), or non-compliant with the topic. The inclusion criteria focus on publications such as conferences, papers, proceedings, or journals, periodicals, publications related to the theme and research questions, articles within the computing and engineering fields, and articles that deeply address critical thinking.

For works on the ACM platform, only those with free and open access were qualified, resulting in a low approval rate due to the lack of availability.

Table 1: Selection Process.

Source	Process evolution results		
	Primary studies	*Exclusion Criterium*	*Quality Criterium*
ACM	147	5	5
IEEE	23	8	5
Scopus	336	96	62
Total	506	109	72

After the filter application, the selected studies were qualified based on quality criteria such as clear methodology, practical application, well-defined model or proposal, discussion of findings, and mention of challenges, limitations, or threats. Each criterium receives a score of 0 (not attended), 0.5 (partially attended), or 1 (attended) for each criterion, totaling a maximum of 5 points, with a minimum of 3 points required to be considered in the study. At the end of this process, *72 primary studies (PS)* are selected for analysis. Figure 2 shows the quality score after the qualification step.

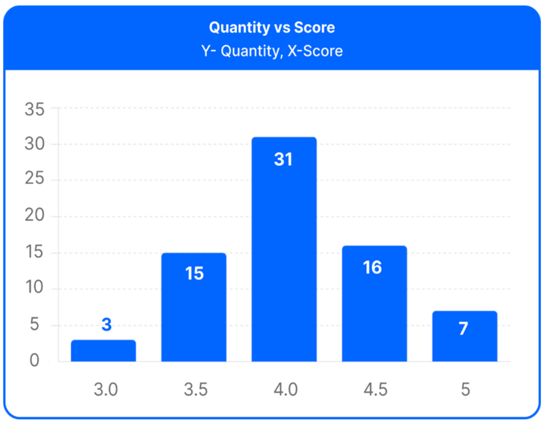

Figure 2: Quantity vs Score.

Figure 3 shows the concentration of studies over time, considering the year of publication of these studies.

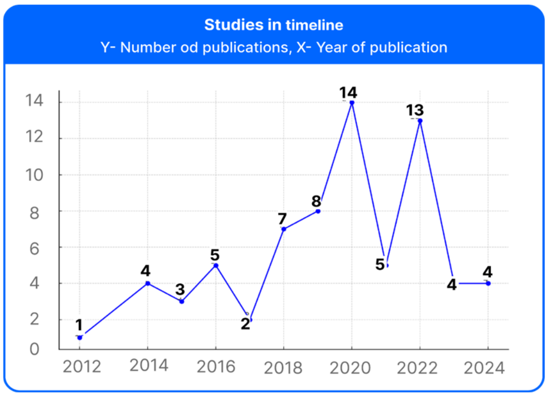

Figure 3: Studies in timeline.

This meticulous procedure ensures that the systematic review produces valuable and reliable insights, as shown by the scoring of studies and their quantities in Figure 2. All studies and details can be found at the spreadsheet-link.

3.4 Review Results

Finally, the results reporting phase is dedicated to synthesizing and presenting the collected information in a manner that effectively addresses the established research questions. This stage not only distills the key insights obtained through the literature review but also evaluates the impact of these findings within the broader context of the field of critical thinking. The discussions focused on theoretical and practical implications, the main results for the development of critical thinking, the limitations encountered, and directions for future research. These topics add depth to the presentation of the results and are vital for providing a significant contribution to the academic community and relevant stakeholders. This step is discussed in detail in the Section 4.

3.5 Limitations, Opportunities and Challenges

A limitation of this systematic review is that some articles on the ACM platform were not available for full viewing. This resulted in the exclusion of studies that could have enriched the analysis of strategies for developing critical thinking in IT students. Future reviews should consider accessing other platforms.

ChatGPT 4.0 Version was a valuable tool during the analysis phase of our studies. It was instrumental in contextualizing key points, calculating data, and generating graphs. For instance, when we needed to create a graph relating each topic to the total percentage of articles, we used the following prompt:

```
create a graph that relates each topic
to the total percentage of articles.
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The output generated by ChatGPT included a clear and informative graph that showed the proportion of studies reporting each type of result, allowing a clear view of the relative impact of each category in the analysed articles

Additionally, ChatGPT was also useful for formatting references according to specific styles. For example, to format a list of references. The response from ChatGPT provided a well-formatted reference list, ensuring that citations were presented correctly and consistently, as shown in Figure 4.

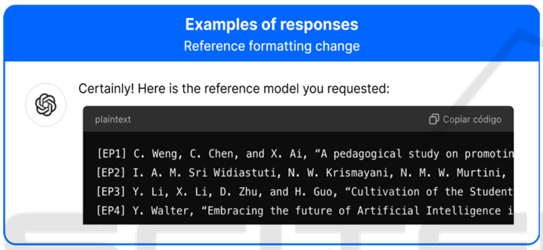

Figure 4: Examples of responses (Reference formatting change).

However, it is important to note that ChatGPT had limitations, including accuracy issues, potential misunderstandings of context, and a reliance on the quality of input provided. Polverini and Gregorcic (2024) emphasize that, although ChatGPT is a powerful tool, its effectiveness in graphical tasks depends on human supervision, as its visual interpretations may not be entirely reliable. To maximize its effectiveness, it was crucial to cross-check information and provide clear, specific inputs. It is also important to emphasize that ChatGPT did not interfere in the definition of the research protocol.

4 RESULTS & DISCUSSIONS

This section will present and discuss the results found, based on a thematic analysis of the data collected, enabling a consolidated view of the answers to the research questions in specific topics. The association between the topics and their related primary studies (PSs) is also available at the spreadsheet-link.

4.1 What Is the Context of the Studies Regarding the Development of Critical Thinking?

The analysed studies encompass a variety of educational contexts, highlighting significant variations in courses, educational level, duration, and class size.

The analysis of some studies, such as PS4, PS32, and PS64, revealed a lack of detail regarding courses, educational level, duration, and class size, making it difficult to evaluate the effectiveness of educational interventions. This absence of information, also present in PS44 and PS47, prevents a comprehensive analysis of the impact of the applied methodologies, limiting their replication in other educational contexts.

4.1.1 Courses

For this analysis, a higher number of studies in Information Technology and Engineering courses were identified (64%), evidenced in studies PS13 and PS43. Other topics include courses in Education (10.8%), Design (6.8%), Psychology (2.7%), Economics (2.7%) and undefined (10.8%). Studies like PS16 focused on reflective practices and critical development, showing an adaptive approach to content that can serve as a reference for IT courses. For courses within Information Technology and Engineering, as well as related fields, we were able to identify subcategories: Engineering (22 studies), General IT (20 studies), Software Development (1 study), and Computer Science (6 studies).

4.1.2 Educational Levels

The analysis of the educational levels of the studies reveals a predominance of research at the undergraduate level, representing most of the PSs, as shown in Figure 5.

This level is frequently addressed in studies on methods and strategies for the development of critical thinking. In contrast, continuing education (PS8, PS19) focused on integrating learning theories and reflective practices, preparing participants for professional education environments. Less frequently explored postgraduate studies, such as PS1 and PS2, emphasize more advanced approaches and strategies adapted to the context of specific disciplines, standing out for their relevance to higher education.

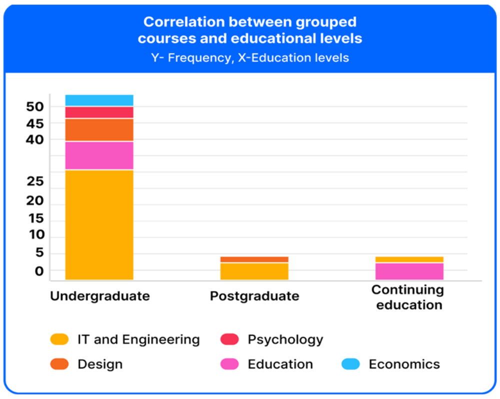

Figure 5: Correlation between grouped courses and educational levels.

4.1.3 Duration of the Course

The duration of the courses varied significantly. Short-term courses (weeks), such as PS13, focused on intensive interventions, providing a concentrated critical learning experience. Medium-term courses (months), such as PS7 and PS60, allowed for a deeper exploration of content, favoring practical application through collaborative projects. Long-term courses (years), such as PS62 and PS66, focused on extensive projects and continuous learning, allowing for sustained development of critical and analytical skills.

4.1.4 Class Size

Class size also played a crucial role. Figure 6 shows an overview of this aspect.

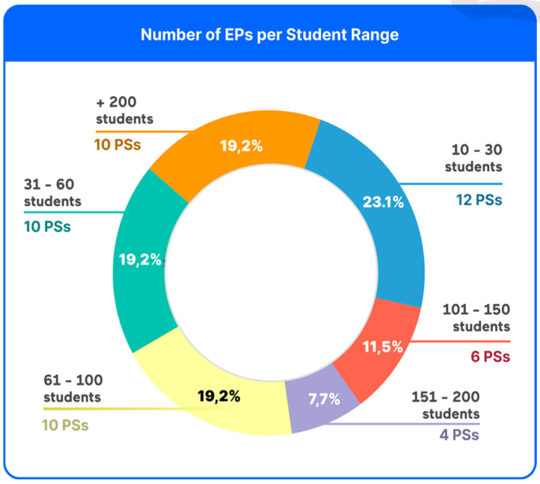

Figure 6: Number of PSs per Student Range.

In small classes, as observed in PS49 and PS53, individualized attention and adaptive instructions were facilitated, promoting an interactive learning environment. Medium-sized classes, such as PS55 and PS58, benefited from a balanced combination of personalized interaction and group dynamics. For large classes, such as PS28 and PS35, the incorporation of educational technologies and online platforms was essential to manage the large number of students and maintain engagement through collaborative activities.

4.2 What Model, Method, Strategy, Technique, and Approach Is Used to Promote Critical Thinking?

Figure 7 presents an overview of the results of this question, which visually shows the concentration of each type of result found.

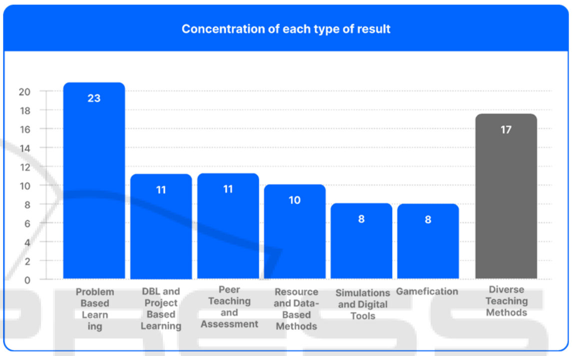

Figure 7: Concentration of each type of result.

4.2.1 Problem-Based Learning (PBL)

Problem-Based Learning (PBL) is a student-centered methodology focused on solving complex and open-ended problems, promoting investigation, critical analysis, and collaboration (Santos et al., 2020). Examples include PS7, PS8, PS10, PS11, PS16, PS17, PS22, PS25, PS26, and PS29. This method is extremely adaptable, providing a range of possibilities and applications, making it the most widely used method among the analysed articles.

In PS7, a feedback feedforward model combined with peer assessment was used to guide students through an iterative and collaborative learning process, enhancing both subject learning and class cohesion. PS8 implemented a contextual learning approach in activities combined with web-based problem-solving, showing significant improvements in students' critical capacity.

PS9 integrated take-home tests, peer instruction, and pre-class videos in an analog circuits course. PS10 used a combination of flipped classroom activities, cloud-based learning, and the use of board games to enhance students' critical thinking skills, being the most outlier and different application of the method observed.

4.2.2 Design-Based Learning (DBL) and Project-Based Learning (PjBL)

The methods of DBL and PjBL are widely used to integrate knowledge from different disciplines through practical projects and design activities, as seen in

PS1, PS11, PS23, PS25, PS26, PS33, PS34, PS39, PS42 and PS63. These methods have proven to be highly effective in developing critical thinking skills, leading to a greater understanding of the course phases.

The "Backward Thinking" model, where the main focus is on defining the final objectives first and then planning the necessary steps to achieve them, had a significant impact in PS1. In this case, six stages were structured, from clarifying the course theme to student assessment, highlighting the importance of an interactive and collaborative learning process.

In PS11, the application of PjBL in engineering courses revealed that students' conceptions of PjBL vary, reflecting different pedagogical beliefs and highlighting the need to adapt the method to the individual needs of students. An important point reported by most PSs is the necessity for students to have a prior understanding of what a project is and how it will be applied in the educational context.

Different contexts were addressed with PjBL. In PS25, a combination of the CDIO (Conceive, Design, Implement, Operate) model was used, while PS28 demonstrated the application of PjBL in business contexts, preparing students to face real-world market problems.

4.2.3 Data and Resource Analysis

These methods, applied in PS12, PS15, PS19, PS30, PS44, PS46, PS51, PS53, PS68, PS71, use structured data and resource analysis to develop students' critical thinking skills. In PS62, the integration of data in field activities and laboratories helped students apply theories in practice.

PS64 addressed the use of data analysis tools to identify trends and patterns, encouraging critical thinking. PSs 68 and 70 explored the use of digital technologies to provide immediate and personalized feedback. PS71 examined the effectiveness of data-driven e-learning tools to support collaborative learning and problem-solving.

4.2.4 Peer Teaching and Assessment

The methods of peer teaching and assessment, applied in PS7, PS9, PS20, PS22, PS24, PS27, PS38, PS55, PS56, PS69 and PS72, promote mutual evaluation among students, encouraging critical reflection and collaborative learning. In PS24, for example, students created and evaluated each other's educational materials, which not only improved their critical thinking skills but also encouraged a deeper understanding of the content.

4.2.5 Simulation and Digital Tools

The analysis of PSs, specifically PS2, PS5, PS6, PS12, PS14, PS18, PS21, PS35, PS37, PS45, PS47, PS50, PS54, PS62, PS64 and PS66, reveals a diversity of methods and approaches for developing critical skills and improving learning. The use of simulations and digital tools is a common strategy, exemplified by PS3, PS5, PS10, PS13, PS31, PS32, PS58, PS68 and PS71, which employ virtual environments and mobile applications to promote critical thinking and context-based learning. In PS3, an NC machining simulation system is introduced, involving students in the creation and operation of virtual models of machine tools. These approaches provide continuous and personalised support, as seen in PS5, which uses mobile devices and software LifeGuide Toolbox to engage students in practical critical thinking activities.

4.2.6 Gamification

Gamification and futuristic technologies, such as AI (Artificial Intelligence), are another recurring theme. PSs such as PS4, PS22, PS36, PS51, PS41, PS52, PS59 and PS65, incorporate game elements and new technologies to increase student motivation and engagement. PS36 develops a gamified learning model that integrates narrative stories, interactive maps, student ranks, and video guides to increase interest in electrical engineering. This model includes four stages of games covering different engineering topics. Each stage has specific requirements, encouraging students to progress through the course in an engaging and interactive manner. PS47 explores the use of blockchain technology for skill recognition and academic record verification, promoting a more engaging learning experience.

Various and innovative teaching methods are also highlighted in PSs such as PS6, PS10, PS12, PS13, PS14, PS15, PS37, PS57, PS58, PS66, and PS67. These studies cover everything from flipped classrooms and problem-based learning to active and collaborative learning methods. PS10, for instance, integrates flipped classroom activities with game-based learning, while PS12 and PS13 use e-learning modules to replace traditional classes, promoting group activities for problem-solving.

4.2.7 Multiple Teaching Methods

The use of multiple teaching methods is a strategy aimed at maximizing pedagogical effectiveness by addressing the diverse learning needs of students. Figure 8 shows a heatmap of this use, considering the studies found.

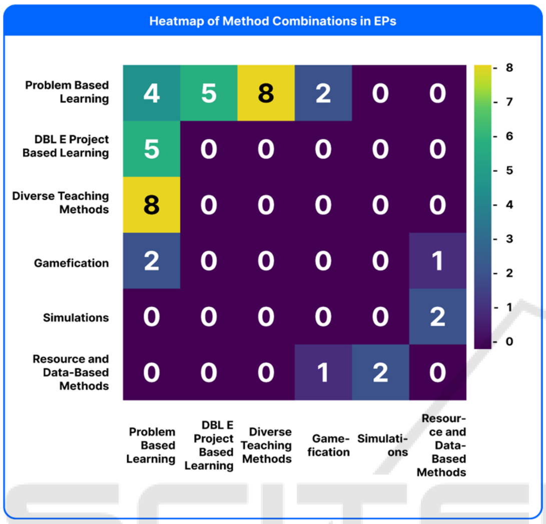

Figure 8: Heatmap of Method Combinations in Eps.

Multifaceted approaches allow educators to combine the strengths of different methods, creating a richer and more engaging learning experience. In PS11, for example, a combination of flipped classroom, problem-based learning (PBL), and board games was used to enhance critical thinking, providing students with a variety of ways to engage with the material. PS12 integrated flipped classrooms with mobile learning and PBL, demonstrating how technology can support different learning styles and facilitate practical application of knowledge.

The most common combination of methods involved integrating PBL with other approaches. PS36 combined gamification within a PBL model, creating an interactive learning environment that encouraged problem-solving and practical application of knowledge. PS41 also integrated PBL and gamification, using game elements to increase student motivation, as a competition for improving their engagement with projects. These combinations proved particularly effective in STEM disciplines, where the practical application of knowledge is crucial.

Additionally, PS48 highlighted the combination of experiential learning with puzzle solving and design thinking, addressing complex problems with user-centered innovative solutions. This multifaceted approach promoted creative and critical problem-solving skills, demonstrating the effectiveness of combining different methods to address various aspects of critical thinking.

The use of multiple teaching methods reflects the need to adapt pedagogical strategies to the varied needs of students, maximizing teaching effectiveness and promoting deeper and more meaningful learning. The combinations of PBL with gamification and experiential learning proved particularly effective, highlighting the importance of continuous innovation in education to meet the challenges and opportunities of the 21st century.

4.2.8 Evolution of Methods over the Years

Between 2012 and 2024, we observed a growing trend of diversification and innovation in teaching methods. In 2012, resource-based and data-driven methods began to gain traction with PS30, which compared traditional assessment with e-assessment, highlighting the importance of using digital tools in education. In 2014, diversification intensified with the introduction of various teaching methods, such as the combination of distance education and PBL in PS41, and the use of humanitarian methods in PS67.

Between 2015 and 2017, there was a significant expansion of problem-based methods, as demonstrated in PS28, which integrated real business problems into ICT classes, and the adoption of innovative teaching and peer assessment methods, as seen in PS23 and PS24. From 2018 to 2020, there was an increase in the use of virtual simulations and digital tools, exemplified by PS3.

Between 2021 and 2023, we observed a significant increase in the application of gamification and futuristic technologies, as in PS36, which created a gamified learning model for engineering students, and in PS47, which proposed the use of blockchain technology for student skill recognition. In 2024, the use of DBL and PBL-based methods was intensified, as seen in PS1 and PS11, along with the continuous integration of advanced technologies as AI in PS4.

4.3 What Are the Main Results Achieved?

The reviewed articles present a wide range of results, including both positive and negative impacts of innovative educational interventions. While many studies highlight significant improvements in academic performance, student attitudes, satisfaction, collaboration, and practical application of acquired knowledge, challenges and negative results also warrant attention. The skills acquired will be discussed in more detail in the following section. Figure 9 shows an overview of specific outcomes.

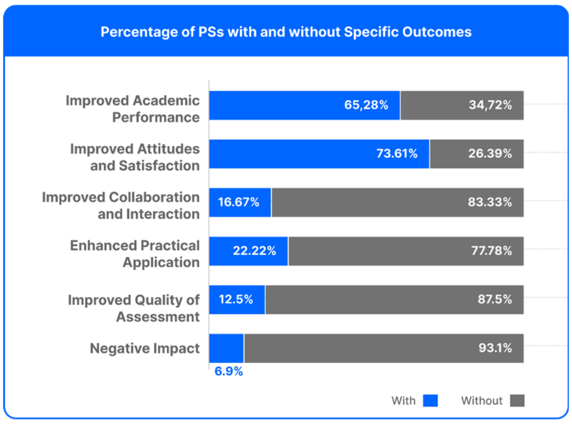

Figure 9: Percentage of PSs with and without Specific Outcomes.

One of the most notable results was the improvement in academic performance. Various studies demonstrated that innovative educational interventions led to a significant increase in student grades. For example, PS1 revealed that students using Design-Based Learning (DBL) had higher grades compared to the control class.

PS13 indicated that students in a flipped section consistently outperformed those in the traditional section in nearly all assessments. In PS26, students in problem-based learning (PBL) achieved an average of 72.5, while the non-PBL group scored 48.74. PS14 highlighted that active learning improved the understanding of scientific concepts and digital skills. PS42 showed that project-based learning (PjBL) resulted in a deeper understanding and practical application of concepts. Finally, PS59 found that 60% of students felt that games increased their motivation and engagement in learning.

Student attitudes and satisfaction also improved significantly in response to new teaching methodologies. PS3 and PS38 reported positive attitudes, with increased satisfaction and confidence in learning abilities. In PS24, students motivated by creative expression saw substantial improvements in grades. PS14 showed that active learning improved the understanding of scientific concepts and developed digital and creative skills. PS42 indicated that project-based learning (PjBL) resulted in a deeper understanding and practical application of concepts. PS59 revealed that 60% of students felt that games increased their motivation and engagement in learning.

Collaboration and interaction among students were highlighted in several studies. PS7 and PS66 indicated that collaborative activities and continuous feedback resulted in better understanding and higher engagement. PS21 and PS52 reported that peer-based learning significantly increased knowledge retention and understanding of complex concepts. PS50 highlighted the use of social media as a useful platform for post-class discussions and collaborations.

Despite many positive results, some studies highlighted challenges and negative outcomes, as shown in Table V. For example, PS6 showed that the intervention group had lower confidence in their critical thinking skills after the intervention, suggesting that some methodologies might increase awareness of personal limitations. PS15 pointed out significant variations in critical thinking assessments by employers, indicating inconsistency in developing these skills. PS39 identified that universal assessment of software development skills was ineffective, with inconclusive results and weak test-retest reliability, highlighting the difficulty of creating standardized assessments for complex competencies. PS18 observed that although innovations in IT-based learning improved material mastery, this improvement did not mediate the relationship between critical thinking skills and academic performance, suggesting that gains in one area do not necessarily translate to another. Finally, PS37 points out the difficulty in correctly incorporating technological tools.

4.4 What Are the Perceived Benefits?

The development of critical thinking skills is the most highlighted benefit in the analysed educational interventions as shown in Figure 10 that illustrates all benefits found.

Practices that require analysis, evaluation, and synthesis of information significantly promote this capability, as observed in PS1, PS21, and PS38. These practices strengthen academic performance and prepare students for complex professional challenges.

Student motivation and engagement are also frequently highlighted. Methodologies such as flipped classrooms (PS10 and PS22), project-based learning (PjBL) as seen in PS43 and PS55, and gamification in PS36 and PS47 play a vital role in student motivation. As these approaches are more dynamic and participatory, they result in greater student involvement and better learning outcomes.

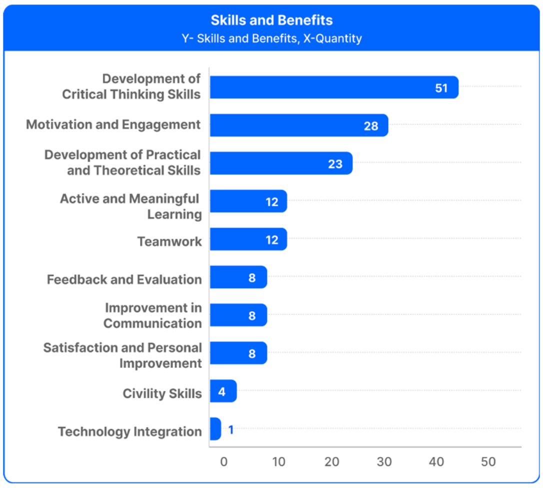

Figure 10: Skills and Benefits.

Improved communication is a significant benefit identified in PS1, PS2, PS11, PS14, PS19, PS27, PS60, and PS68.

The combination of theory and practice, especially in fields such as engineering and computer science, is highlighted as an effective means to develop practical and theoretical skills (PS2, PS3, PS6, PS49 and PS51), better preparing students for the job market.

Active and meaningful learning provides lasting learning for students and is applicable to other areas of life (PS19, PS24, PS62 and PS65). Likewise, continuous and constructive feedback is crucial for skill development, helping students identify areas for improvement and develop competencies more effectively (PS7, PS20, PS23, PS27, PS38, PS46, PS49 and PS66).

Teamwork is essential for developing interpersonal and collaborative skills. Methodologies that encourage cooperation and interaction among students are effective in developing this competence (PS56, PS62 and PS68).

Collaborative activities, group discussions, and continuous feedback develop effective communication skills, enhancing interpersonal skills and the ability to work in teams.

Satisfaction and personal improvement are achieved through methods that encourage individual growth and self-assessment, enriching students with personal development benefits and skills (PS8, PS9, PS19 and PS31).

Although the development of critical thinking skills is the main focus of this study, not all analysed PSs directly addressed this competence. Some PSs highlighted other benefits such as motivation and engagement, teamwork, and others, which are fundamental and, to some extent, related to the development of critical thinking. This suggests that innovative pedagogical practices not only contribute to a dynamic and engaging learning environment but also, even if not explicitly focused on it, promote critical thinking by developing skills that help students and pave the way for more complex skills such as critical thinking to be effectively developed.

4.5 What Challenges Were Encountered?

Figure 11 shows an overview of main challenges found.

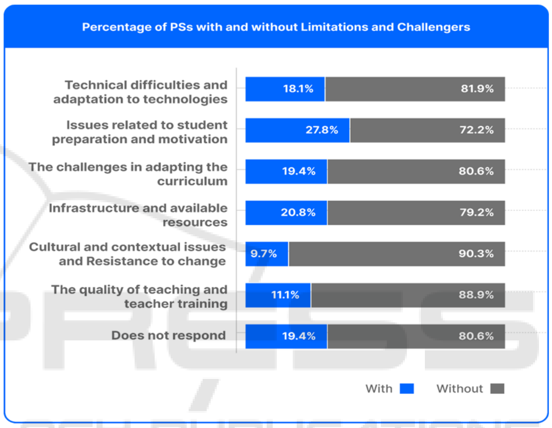

Figure 11: Percentage of PSs with and without Limitations and Challenges.

Technical difficulties and adaptation to technologies are frequently mentioned as significant challenges. Many students faced problems with the technical complexity of the technology, as in the case of PS3, PS13, PS54, and PS59, or a lack of familiarity with new technologies, as reported in PS1, PS4, PS37, and PS51. PS4 emphasizes that AI in education enables personalized learning and supports diverse needs but requires extensive educator training and curriculum adaptation to meet societal standards. Additionally, there were difficulties with specific tools, such as the lack of customization of assessment tools (PS32) and adaptation to digital platforms (PS50). These difficulties can negatively impact engagement and learning effectiveness.

Infrastructure and available resources also represent considerable challenges. The lack of adequate infrastructure to support project-based teaching methods and advanced technologies was highlighted in PS25, PS42, and PS53. Without the necessary resources, it is difficult for educators to implement and sustain these innovations effectively. Additionally, the resource of time presents specific challenges, such as the need for more continuous support and longer durations for effective educational interventions, which in turn increases the demand for this resource (PS5, PS48, PS49, PS59, and PS72).

The quality of teaching and teacher training are other areas of limitation. Teachers often feel overwhelmed or insufficiently prepared to implement new technologies and teaching methods, as observed in PS16, PS17, PS45, and PS59. PS12, PS25, PS29, and PS64 also highlight the challenges in adapting the curriculum to include innovative methodologies, which demand effort and time. Continuous training and support for teachers are essential to ensure the effectiveness of new educational approaches.

Issues related to student preparation and motivation were also identified. For example, in PS2 and PS37, initial difficulties in effective communication between teachers and students, especially in online teaching, and student disinterest due to a lack of detailed explanations from teachers were highlighted. In PS9, many students did not follow the instructions for pre-reading materials, compromising effective participation in discussions, as in PS65. In the meantime, PS26 emphasized the need to ensure that increased student motivation is not just a temporary effect. This reflects the need for strategies that encourage student preparation and engagement before activities.

Cultural and contextual issues also influence the effectiveness of educational interventions. Factors such as the cultural expectations of students and teachers can affect the acceptance and effectiveness of new teaching methods, as observed in PS17, PS49, and PS50. Adapting teaching methods to specific cultural needs is crucial for the success of these strategies. Resistance to change is also a significant barrier. The implementation of these innovative strategies can face resistance from teachers, administrators, and even the students themselves, as highlighted in PS52, PS54, and PS68. Cultural change within educational institutions is necessary to accept and effectively incorporate new teaching approaches.

4.6 Critical Thinking Skills Guideline

Considering the strategies for developing critical thinking skills in technology students that were mapped in this systematic study and the possibility of using these strategies, even in the face of some challenges, Figure 12 presents a consolidated summary in guideline format, highlighting the main characteristics, impacts, and benefits of each one.

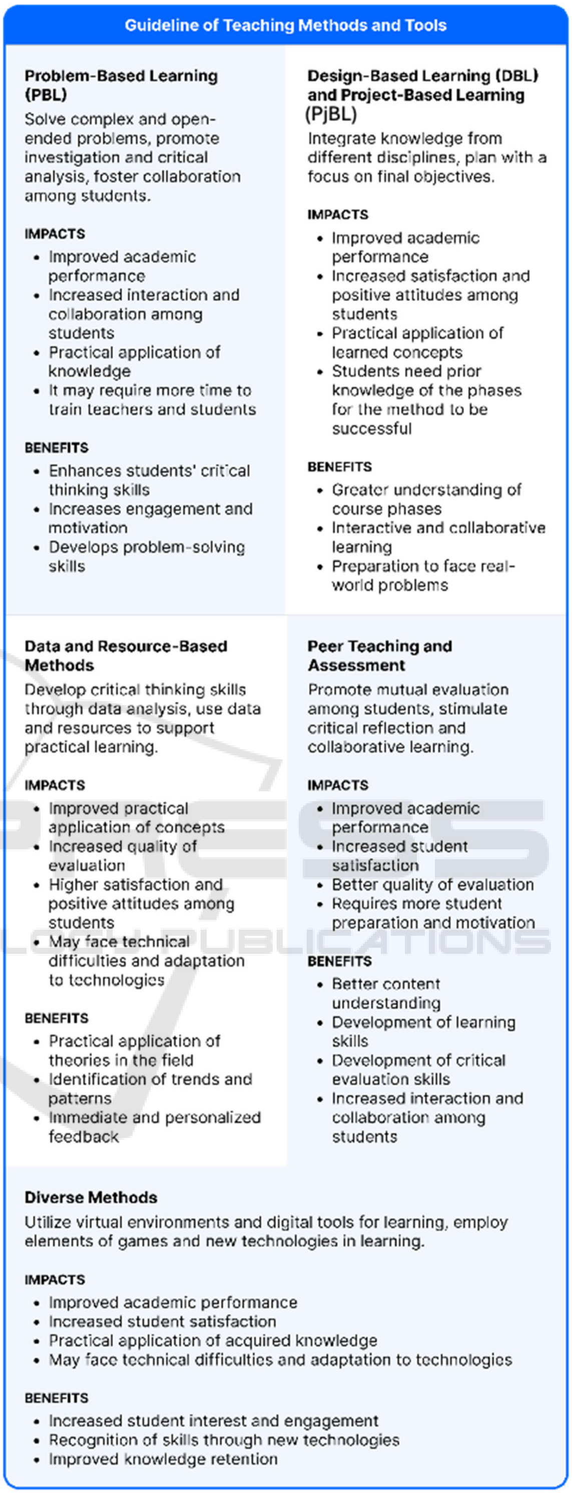

Figure 12: Guideline of Teaching Methods and Tools.

5 CONCLUSIONS

In summary, this mapping study (MS) on strategies for developing critical thinking in Information Technology (IT) students highlights the importance of innovative pedagogical methods to prepare students for the challenges of the digital world. Through the analysis of multiple studies, it was possible to identify those methodologies such as Problem-Based Learning (PBL), Design-Based Learning (DBL), and gamification significantly enhance critical thinking skills by providing dynamic and interactive learning environments.

Issues related to student preparation and motivation were also identified. For example, in PS2 and PS37, initial difficulties in effective communication between teachers and students, especially in online teaching, and student disinterest due to a lack of detailed explanations from teachers were highlighted. In PS9, many students did not follow the instructions for pre-reading materials, compromising effective participation in discussions, as in PS65. Meanwhile, PS26 emphasized the need to ensure that increased student motivation is not just a temporary effect. This reflects the necessity for strategies that encourage student preparation and engagement before activities.

Cultural and contextual issues also influence the effectiveness of educational interventions. Factors such as the cultural expectations of students and teachers can affect the acceptance and effectiveness of new teaching methods, as observed in PS17, PS49, and PS50. Adapting teaching methods to specific cultural needs is crucial for the success of these strategies. Resistance to change is also a significant barrier. The implementation of these innovative strategies can face resistance from teachers, administrators, and even the students themselves, as highlighted in PS52, PS54, and PS68. Cultural change within educational institutions is necessary to accept and effectively incorporate new teaching approaches.

Future studies could explore the longitudinal effects of critical thinking strategies on IT students, compare effectiveness across different cultural contexts, or examine how emerging AI tools further enhance critical thinking skills in IT education. Investigating interdisciplinary approaches could also reveal insights for broader educational applications.

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