UNIVERSIDADE FEDERAL DE PERNAMBUCO

DANIEL JOSÉ DA SILVA

HOW TO TEACH INNOVATION TO STUDENTS IN HIGHER EDUCATION COMPUTING

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SISTEMAS DE INFORMAÇÃO

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TCC apresentado ao Curso de Sistemas de Informação da Universidade Federal de Pernambuco, como requisito para a obtenção do título de Bacharel em Sistemas de Informação.

Orientadora: Prof. Simone Cristiane dos Santos Lima

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Aprovado em: __/__/____

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How to Teach Innovation to Students in Higher Education Computing

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***Abstract*—This systematic literature review (SLR) investigates methods for teaching innovation to adult learners in higher education computing programs, with the aim of developing a comprehensive portfolio of pedagogical solutions. By analyzing peer-reviewed studies, the research identifies and categorizes educational practices—ranging from traditional classroom approaches to experiential, project-based, and interdisciplinary methods—that foster creativity, problem-solving, and entrepreneurial mindsets. The review highlights recurring themes such as the role of industry collaboration, hackathons, design-thinking workshops, and innovation labs in bridging theoretical knowledge with real-world challenges. Findings suggest that blended pedagogical models, which integrate hands-on learning with reflective practice, show significant promise in cultivating innovation capabilities. This study contributes to a structured framework for educators and policymakers to redesign curricula, ensuring alignment with market demands while addressing gaps in current educational strategies.**

***Keywords*—Innovation education, systematic literature review, higher education computing, ICT, teaching methods, adult learners, curriculum design.**

I. Introduction

Innovation is a process that involves the creation and application of novel ideas, methodologies, or technologies to generate value and improve outcomes. In the context of computing education, it entails the development of new pedagogical strategies, the integration of emerging technologies, and the cultivation of creativity. As noted by Xu, effective innovation hinges on continuous experimentation, collaborative efforts, and the capacity to adapt to evolving challenges [38].

In this regard, innovation has become a crucial competency in the field of computing, as rapid technological advancements continually reshape industry demands, as discussed by Chen et al. (2021) [4], Dai (2023) [5], and Duan et al. (2021) [7]. As the Information and Communication Technology (ICT) sector evolves, higher education institutions face mounting pressure to equip students not only with technical expertise but also with the skills to think creatively, solve complex problems, and drive technological progress [11], [24], [46].

However, fostering innovation in computing education presents distinct challenges, as traditional pedagogical approaches often prioritize technical proficiency over creative problem-solving and interdisciplinary thinking [26], [28], [30], [31], [32]. Consequently, the focus on cultivating innovation requires a shift from conventional teaching paradigms that emphasize rote learning to more dynamic, inquiry-based approaches that nurture critical thinking and creativity.

Innovation operates on multiple levels, ranging from incremental improvements to radical breakthroughs. For computing professionals, innovation is essential, as it drives technological progress, enhances operational efficiency, and addresses complex problems. It facilitates the development of new software, algorithms, and systems that transform industries and improve quality of life. The significance of innovation in computing lies in its capacity to foster competitiveness and adaptability.

According to Luo et al. (2023) [26] and Mu et al. (2022) [28], professionals who engage in innovative practices are better equipped to address emerging challenges, such as cybersecurity threats or scalability issues, while simultaneously creating value for society. By incorporating innovative thinking, computing professionals can push the boundaries of the field, ensuring sustainable progress and maintaining a competitive edge in a rapidly evolving landscape [40].

This study aims to explore and analyze methods for teaching innovation in higher education computing programs through a Systematic Literature Review (SLR). By examining existing pedagogical frameworks, instructional strategies, and emerging trends, this research seeks to develop a comprehensive portfolio of solutions to assist educational institutions in fostering innovation among ICT students [33], [47].

Additionally, the study investigates the anticipated benefits of these approaches, as well as the challenges educators face when implementing innovation-centered curricula.

This paper is organized into five sections. This section presents a brief introduction, which defines innovation and contextualizes the work, Section II describes the systematic investigation research method used in this study. Section III presents a qualitative analysis of the studies analyzed, followed by Section IV, which presents a brief discussion of the results. Finally, Section V describes the concluding remarks.

II. Research Method

This research adhered to the guidelines set forth by Kitchenham [19] for conducting a Systematic Literature Review (SLR), a method designed to systematically identify, evaluate, and interpret all available research related to a specific question, topic, or phenomenon of interest. The SLR methodology is widely used in the field of technology, as demonstrated in the works of Delgado Kloos et al. (2021) [6] and Singelmann & Ewert (2022) [30], both of which are referenced in this study.

The primary objective of conducting an SLR is to ensure a comprehensive and rigorous examination of the existing literature, thereby enhancing the scientific validity and reliability of the research [3], [8], [15]. By employing this approach, it is possible to obtain a structured overview of the various methods used to teach innovation in higher education computing programs, analyzing studies that explore different practices, models, and challenges within the field [9], [36].

Furthermore, a well-defined methodology reduces the potential for bias, facilitates the examination of a broad range of contexts and empirical approaches, and supports the systematic organization of data. This process ultimately contributes to the development of a comprehensive portfolio of educational solutions.

The review was conducted in three key stages: Planning the Review, Conducting the Review, and Systematizing the Results. These stages ensured a rigorous, transparent process for data collection and analysis, thereby enhancing the reliability and replicability of the study.

To ensure a rigorous and systematic approach to this literature review, we adopted the methodology proposed by Kitchenham et al. [19] for conducting systematic literature reviews in software engineering. This methodology consists of three main stages: Planning, Conducting, and Reporting. Figure 1 illustrates the process.

II.1 Planning the systematic literature review

The planning stage established the research protocol to ensure reproducibility and minimize bias. This phase involved defining research questions, determining search strategies, and specifying inclusion and exclusion criteria. The study aimed to answer three Research Questions (RQ) regarding the teaching of innovation in computing education:

- *RQ1*: What solutions are currently employed in teaching innovation?
- *RQ2*: What are the expected benefits of these solutions in fostering innovation among computing students?
- *RQ3*: What are the main challenges of teaching innovation in higher education computing programs?

Search Strategy: The review considered multiple academic databases (Scopus, IEEE Xplore, and ACM Digital Library) to ensure comprehensive coverage. Boolean operators were used to structure a search string (*("teach innovation" OR "teaching innovation" OR "stimulate innovation" OR "increase innovation") AND (classrooms OR education OR school) AND (model OR method OR strategy OR strategies OR methodology OR practices)*) with key terms related to teaching innovation, educational contexts, and methodological approaches [14].

Data Collection: The search yielded 390 articles, which were exported to a structured spreadsheet. Duplicates were removed using Zotero, and articles were screened based on relevance, prioritizing those focused on pedagogical practices, teaching models, and institutional challenges.

Inclusion and Exclusion Criteria: The review included peer-reviewed journal articles and conference papers published between 2019 and 2024, available in English, and relevant to computer science and ICT education. Studies on K-12 education (educational system for students from kindergarten through 12th grade), unrelated technical fields, and those lacking full-text access were excluded.

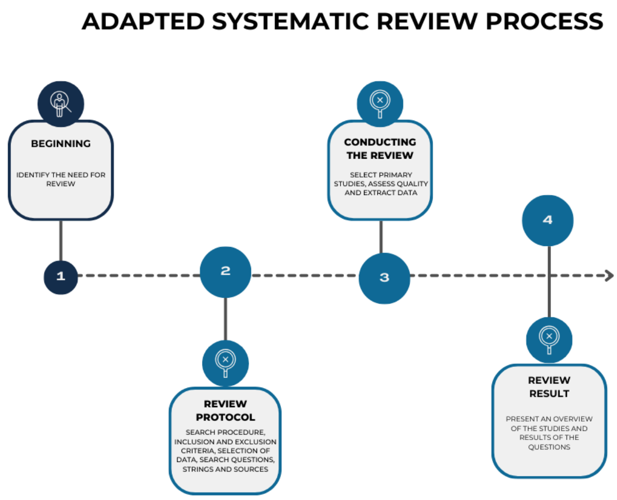

Fig. 1. Systematic Review based on Kitchenham (2009).

II.2 Conducting the review

After defining the inclusion criteria, the screening process was conducted in two phases:

- *Title and Abstract Screening*: Initial selection of relevant studies based on title and abstract. A total of 390 articles were reviewed, with 107 advancing to the next phase.
- *Introduction and Conclusion Screening*: Articles flagged as ambiguous were further assessed. Final selection included 46 studies that met the inclusion criteria.
- *Quality Assessment*: Selected studies were evaluated using six criteria, including methodological rigor, clarity, contribution to the field, and practical applicability, quality of the references and relevance to the theme. A scoring system that used three options (0, 0.5, 1.0) was applied, with studies scoring at least 5.5 out of 6.0 advancing to synthesis.

- *Data Synthesis*: The final dataset was categorized into thematic clusters such as project-based learning, industry collaboration, and curriculum design, facilitating comparative analysis.

On figure 2 a table presents the filtered result. 46 studies, including their PS, title, and year of publication. And figure 3 shows the number of studies divided by databases.

ID	Title	Year	URL QC
PS40	Practice Research on School-enterprise Cooperative Innovation and Entrepreneurship Collaborative Education Information Platform	2024	4
PS41	Research on Collaborative Innovation Ability Training of Software Engineering Talents Based on the Industry-Education Integration	2024	4
PS42	Research on the Practice Education Pattern of Innovative Entrepreneurship in Colleges in the Internet Plus Era	2024	4
PS43	Application of Flipped Classroom Teaching Method in the Single-Chip Microcomputer Course	2024	4.5
PS44	Application of Generative Artificial Intelligence Technology in Customized Learning Path Design: A New Strategy for Higher Education	2024	4
PS45	Intent Research on the Use of Generative AI by Student Teachers: An Integration Model Based on S-O-R and TAM	2024	4.5
PS46	Integrating CDIO and Problem Based Learning Framework for Industrial Internet of Things Training Course Development	2024	4.5

ID	Title	Year	URL QC
	Technology		
PS15	Research on Digital Circuit Teaching Reform and Innovation Practice of Software Engineering Specialty under Engineering Education	2021	5
PS16	Creation of a Framework that Integrates Technical Innovation and Learning in Engineering	2021	4.5
PS17	BITS: A Blockchain-Based Intelligent Teaching System for Smart Education	2021	4.5
PS18	Scratch Teaching Mode of a Course for College Students	2021	4.5
PS19	Study on the application of learner's output-oriented Feynman-five-energy method in computer teaching	2021	4
PS20	Reform and practice of open teaching mode based on innovation ability training	2021	4
PS21	The research on talent education for AI-based IoT system development and implementation by the CDIO concept	2022	5
PS22	PROF-XXI: Teaching and Learning Centers to Support the 21st Century Professor	2022	4.5
PS23	Design of PBL Teaching Method Based on OBE Mode	2022	4
PS24	Reform of Cultivating Practical Innovation Ability in Computer Science	2022	5.5
PS25	Multilevel-teaching/training practice on GNSS principle and application for undergraduate educations: A case study in China	2022	5
PS26	Research on Case Method in Engineering Cognition and Practice	2022	5
PS27	Cultivation Design of Applied Undergraduates' Engineering Innovation Ability Based on Virtualization Technology	2022	4.5

ID	Title	Year	URL QC
	Technology		
PS15	Research on Digital Circuit Teaching Reform and Innovation Practice of Software Engineering Specialty under Engineering Education	2021	5
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PS19	Study on the application of learner's output-oriented Feynman-five-energy method in computer teaching	2021	4
PS20	Reform and practice of open teaching mode based on innovation ability training	2021	4
PS21	The research on talent education for AI-based IoT system development and implementation by the CDIO concept	2022	5
PS22	PROF-XXI: Teaching and Learning Centers to Support the 21st Century Professor	2022	4.5
PS23	Design of PBL Teaching Method Based on OBE Mode	2022	4
PS24	Reform of Cultivating Practical Innovation Ability in Computer Science	2022	5.5
PS25	Multilevel-teaching/training practice on GNSS principle and application for undergraduate educations: A case study in China	2022	5
PS26	Research on Case Method in Engineering Cognition and Practice	2022	5
PS27	Cultivation Design of Applied Undergraduates' Engineering Innovation Ability Based on Virtualization Technology	2022	4.5

ID	Title	Year	URL QC
PS28	Online and Offline Blending Learning Exploration of Data Mining Course Based on Internet+	2022	4.5
PS29	Cultivation Path for Innovation Ability of Sci-Tech Talents in the Background of Big Data	2022	4.5
PS30	Discussion on the Cultivation of Innovation Ability in Engineering Drawing Teaching Under the Background of "Emerging Engineering Education"	2022	4.5
PS31	Leveraging the Innovation-Based Learning Framework to Predict and Understand Student Success in Innovation	2022	4.5
PS32	Enhancing design thinking in engineering students with project-based learning	2023	5.5
PS33	Design and Implementation of College Students' Innovation and Entrepreneurship Experience System Based on Multidimensional Dynamic Innovation Model	2023	5.5
PS34	Project-based learning in human-computer interaction: a service-dominant logic approach	2023	5.5
PS35	Design of innovation ability evaluation model based on IPSO-LSTM in intelligent teaching	2023	4.5
PS36	Cultivation Model of Mechanical Students Based on Integration Between Industry and Education	2023	4.5
PS37	Online Teaching Design and Evaluation of Innovation and Entrepreneurship Courses in the Context of Education Interactionalization	2023	4
PS38	Exploration and Practice of Digital Technology Empowering Training of Engineering Innovation Talents	2023	4
PS39	Exploration on Blended Teaching Mode of Data Mining Course with CDIO Concept	2023	4.5

Fig.2. List of all 46 studies analyzed.

II.3 Limitations and threats to validity

Despite the rigorous methodology employed, several limitations must be acknowledged:

- Database Coverage: While Scopus, IEEE Xplore, and the ACM Digital Library are extensive, some relevant studies from other sources may have been overlooked.

- Publication Bias: The exclusion of non-English publications may have led to the omission of valuable research.

- Time Constraints: The analysis focused on studies published between 2019 and 2024, potentially overlooking earlier foundational work.

By adhering to systematic guidelines (e.g., PRISMA) and ensuring transparency in the methodology, this study aims to provide a reliable and replicable analysis of innovation teaching in computing education.

	IEEE	ACM	Scopus	Total
Articles found	85	51	254	339
Filter 1 **Title and abstract**	30	10	64	94
Filter 2 **Introduction and conclusion**	32	0	64	96
Classification	18	0	35	53
Selected	18	0	35	46*

Figure 3: Filter results.

III. Selection criteria

The selection of studies for this review followed a systematic process detailed in Section II (Research Method). The main limitations include the restriction to articles in English, the publication period (2019-2024) and the removal of unavailable articles. Despite this, the process minimized bias.

III.1 What solutions are currently employed in teaching innovation?

This question includes an analysis of methods, models, and practices, requiring categorizing different approaches, as shown in Figure 4.

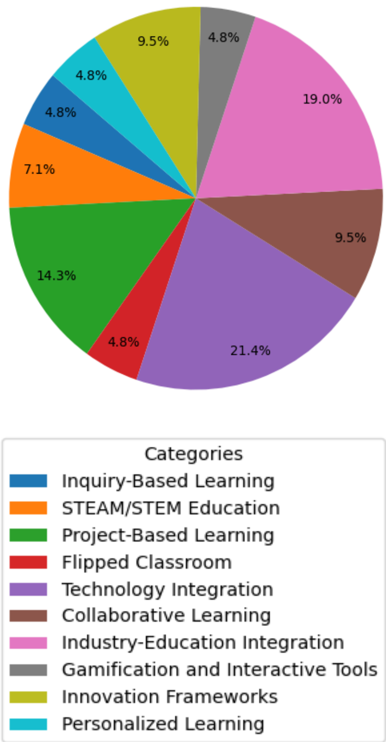

Fig. 4. Q1 categories - Solutions applied.

The study in [14] revealed that structured, activity-based frameworks—such as maker education and STEAM integration—are highly effective for teaching innovation and practical skills in higher education computing. Key methods include inquiry-based activities, blended learning, and collaborative tasks, which were shown to enhance computational thinking and professional competencies. The research also identified advanced assessment tools as critical for evaluating student outcomes [13]. Quantitative models (e.g., IPSO-LSTM algorithms) and multidimensional frameworks (e.g., AHP-weighted indicators) were validated as reliable methods for measuring innovation and skill development [39].

Additionally, digital tools, gamification strategies, and AI-driven platforms were found to improve problem-solving abilities and technical proficiency significantly. Problem-based learning/Project-based learning (PBL) emerged as a cornerstone of innovation education, integrating design thinking, emotional intelligence, and real-world applications [26].

Approaches such as flipped classrooms, virtual simulations, and robotics (e.g., LEGO MINDSTORMS) were highlighted for their ability to engage students and bridge theoretical knowledge with practical challenges [12].

In summary, the studies presented the following evidence:

- Inquiry-based activities, blended learning, and collaborative tasks, which enhance computational thinking and professional competencies, mainly according to Cao et al. (2021) [2] and Li et al. (2024) [22].

- Advanced assessment tools, including quantitative models (e.g., IPSO-LSTM algorithms) and multidimensional frameworks (e.g., AHP-weighted indicators), validated for measuring innovation and skill development [13].

- Digital tools, gamification strategies, and AI-driven platforms significantly improve problem-solving abilities and technical proficiency [35].

- Project-based learning, integrating design thinking, emotional intelligence, and real-world applications, as a cornerstone of innovation education [17], [29].

- Flipped classrooms, virtual simulations, and robotics (e.g., LEGO MINDSTORMS) as methods to engage students and bridge theoretical knowledge with practical challenges [12], [25].

These findings provide a comprehensive portfolio of strategies for educators and institutions seeking to prepare students for the evolving demands of the ICT sector.

III.2 What are the expected benefits of these solutions in fostering innovation among computing students?

Diverse benefits were found from the selected studies, as shown in Figure 5.

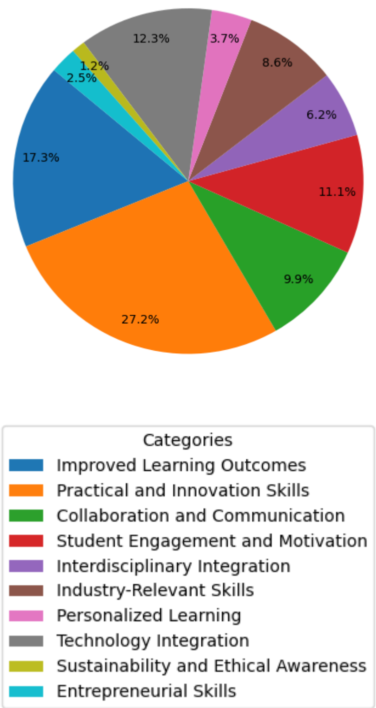

Fig. 5. Q2 categories - Expected benefits.

The research findings indicate that the integration of innovative teaching methods significantly fostered innovation and enhanced the skills of computing students [18]. By incorporating project-based learning and interdisciplinary approaches, students were able to engage in practical problem-solving, which deepened their understanding of core computing concepts. This approach allowed students to actively apply theoretical knowledge in real-world scenarios, improving both their academic performance and their ability to tackle complex issues [43].

The results showed a notable improvement in students' practical skills, particularly in areas such as communication, collaboration, and critical thinking, all of which are essential for success in the technology sector. Additionally, the study in [37] highlighted that the new teaching strategies had a positive impact on students' creativity and independent learning. Students displayed greater enthusiasm for learning and were more willing to engage in self-directed projects [16].

The research found that the use of these methods not only enhanced students' technical knowledge but also contributed to their ability to innovate. The development of skills like adaptability and problem-solving further equipped students to thrive in the fast-paced and ever-changing computing industry, demonstrating the long-term benefits of fostering an innovation-driven learning environment. Furthermore, the research confirmed that the innovative teaching model improved the overall employability of students.

The approach helped bridge the gap between academic knowledge and the practical skills required by the industry [27]. Students reported higher levels of satisfaction with the course and expressed confidence in their ability to solve real-world problems. By preparing students with a blend of technical expertise and soft skills, such as teamwork and adaptability, the study suggests that these teaching solutions are essential in shaping the next generation of computing professionals who are ready to meet the challenges of the global job market.

In summary, the studies presented the following evidence concerning benefits:

- Enhanced practical skills: Students improved in communication, collaboration, and critical thinking, essential for success in the technology sector [18], [32].

- Deeper engagement and motivation: Interdisciplinary and project-based approaches fostered greater enthusiasm for learning and encouraged self-directed projects [16].

- Stronger problem-solving and adaptability: Students developed a capacity to apply theoretical knowledge in real-world scenarios, increasing their ability to tackle complex challenges [43].

- Improved employability: By bridging the gap between academic learning and industry needs, these methods equipped students with both technical expertise and essential soft skills, such as teamwork and adaptability [27], [37].

The research confirms that fostering an innovation-driven learning environment positively impacts students' creativity, independent learning, and long-term career readiness.

III.3 What are the main challenges of teaching innovation in higher education computing programs?

Some challenges were found from the selected studies, as shown in Figure 6.

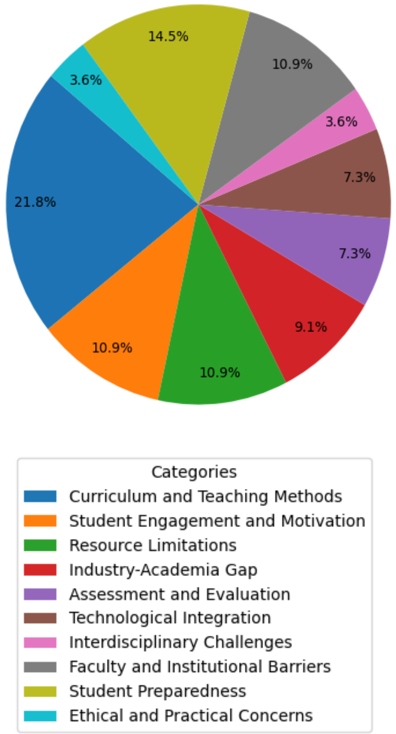

Fig. 6. Q3 categories - Challenges.

The current research found that one of the main challenges in teaching innovation in higher education computing programs is the predominance of traditional, theory-based teaching methods [11].

These approaches often focus on transmitting theoretical knowledge without sufficient emphasis on practical application or fostering creative thinking. As a result, students struggle to develop critical and innovative skills, limiting their ability to apply knowledge to real-world problems [39].

This lack of practical engagement leads to reduced participation and initiative from students, hindering their development of hands-on operational abilities [41]. Another challenge highlighted by the research is the disconnect between academic curricula and the rapidly evolving technology landscape [44].

The study found that many programs fail to keep pace with industry demands, resulting in outdated course content and insufficiently developed skill sets in students. Furthermore, the rapid development of technology creates an additional burden on educators, who must constantly update teaching materials and methodologies to maintain relevance. This gap between education and industry needs makes it difficult for students to be adequately prepared for the workforce [20].

Lastly, the research pointed to shortcomings in assessment methods as a major barrier to fostering innovation in computing education. Traditional evaluation systems tend to focus on theoretical understanding rather than assessing students' practical problem-solving abilities or their innovative processes. This creates an environment where students are not encouraged to develop the critical thinking and creative skills necessary for innovation.

The study suggests that more dynamic and comprehensive evaluation frameworks are needed to better measure students' progress and capabilities in real-world contexts, helping bridge the gap between academic learning and practical application.

In summary, the studies presented the following evidence concerning challenges:

- Prevalence of traditional teaching methods: Many courses prioritize theoretical knowledge over practical application, limiting students' ability to develop critical thinking and creative problem-solving skills [10], [11].
- Mismatch between curricula and industry demands: Rapid technological advancements outpace updates in academic programs, resulting in outdated content and insufficiently developed skill sets in graduates [39], [41].
- High adaptation demands on educators: Instructors face difficulties in continuously updating teaching materials and methodologies to remain relevant [44].
- Limitations in assessment methods: Traditional evaluation systems focus primarily on theoretical understanding rather than on practical application and innovative problem-solving [20].

The study suggests that more dynamic and comprehensive assessment frameworks are necessary to measure students' progress and capabilities effectively, ensuring that academic learning aligns with real-world industry needs [42], [34].

IV. Discussion

IV.1 Innovation models

The study identified several effective methods for teaching innovation in higher education computing programs, including project-based learning, design thinking workshops, hackathons, and industry collaboration [26], [48]. Project-based learning emphasizes hands-on problem-solving, fostering practical skills, while design thinking workshops prioritize user-centered creativity. Hackathons encourage rapid prototyping under time constraints, facilitating innovation in high-pressure environments.

Also, industry collaboration bridges academic theory with real-world challenges, allowing students to apply knowledge in practical settings. These approaches integrate technical skills with innovative thinking, preparing students for dynamic careers in computing.

IV.2 Perceived benefits

These strategies promote essential skills and prepare students to apply theoretical knowledge in practice, aligning with the demand for professionals who connect academia and the market [21].

IV.3 Challenges

While these approaches strengthen the link between academia and industry and promote innovation and entrepreneurship [23, 45], it is crucial to recognize the challenges to ensure that training meets the needs of the technology sector.

V. Final considerations

This study highlights the importance of industry collaboration and hands-on learning experiences in cultivating innovative skills among computing students.

By equipping students with the necessary tools and knowledge, these methods prepare them to drive technological progress and meet the changing demands of the market.

Future research should examine the long-term effects of industry collaborations and experiential learning on students' careers and technological contributions. Additionally, studies could evaluate different experiential learning models in various contexts to identify effective practices for integrating real-world challenges into computing curricula. Strengthening industry partnerships and assessing their role in fostering innovation will be crucial for aligning academic training with the technology sector's evolving needs.

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[49]

Appendix A – AI Prompts and Tools Used

Document with all the RSL process:
https://docs.google.com/spreadsheets/d/1dLHaLfxX_B8Hr5LisP-L9_WHglrJhyLisf7dRbRQb7Q/

AI Tools Utilized:

- **DeepSeek Chat** (https://www.deepseek.com)

Prompts:

1. **Initial Research Guidance Prompt:**
   "I am conducting a systematic literature review. Some key details about my research are:
   - *Research Topic:* How to teach innovation to higher education computing students? A study on opportunities and challenges.
   - *Research Objectives:* Analyze and describe methods for teaching innovation in higher computing education, focusing on adult learners in ICT programs, through a Systematic Literature Review (SLR) to develop a comprehensive solutions portfolio. By examining and categorizing various solutions—from traditional to innovative approaches—the goal is to create a portfolio that benefits educational programs.
   - *Motivation/Justification:* This research addresses the growing need to prepare computing students for a rapidly evolving job market. With fast-paced technological changes and increasing demand for innovation, educational programs must provide not only theoretical knowledge but also practical and creative skills. The study aims to identify effective teaching methods to ensure graduates remain competitive in the ICT sector.
   - *Central Research Question:* How can innovation be effectively taught to higher education computing students?

   I am currently addressing secondary research questions. Please analyze this paper and create a table with columns for each secondary question below, filling them with exact excerpts from the paper. If no answer exists, mark as 'no comments'. For multiple answers, label them (a, b, c...).
   Secondary Questions:
   - *What solutions are used?* (methods, models, practices—needs categorization)
   - *What are the expected key benefits of these solutions?*
   - *What are the main challenges in teaching innovation?*

   Be as critical as possible in your evaluation."
2. **Data Extraction and Categorization Prompt:**
   "Extract responses from the column corresponding to Q1 ('What solutions are currently employed in teaching innovation?').
   - *Identify key themes, patterns, and recurring topics (up to 10 categories).*
   - *Assign each response to relevant categories, noting the source ID (PS1, PS2, etc.).*
   - *Summarize the categories, explaining classification criteria.*
   - *If a response doesn't fit existing categories, create a new one with justification.*
   - *If no response exists, label as 'No response'—do not exclude any article.*