BIBLIOMETRIC ANALYSIS OF THE ROLE OF DIGITAL GAME-BASED LEARNING IN ENHANCING COMPUTATIONAL THINKING SKILLS IN VOCATIONAL SCHOOLS

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ABSTRACT

This study aims to map trends and developments in the literature on the impact of Digital Game-Based Learning (DGBL) on students' Computational Thinking (CT) skills in vocational education using a bibliometric and systematic literature review (SLR) approach. Data were collected from the Publish or Perish database (Google Scholar), yielding 135 articles that were subsequently screened down to 10 final journals. Bibliometric analysis was conducted with R Studio, and keyword mapping was visualized using VOSviewer, including citation analysis, publication trends, h-index (50) and g-index (100) metrics, and co-word mapping to reveal major topic clusters. The findings indicate a rise in both publications and peak citations in 2022, an average of 182.96 citations per paper, and interdisciplinary author collaborations averaging 2.68 authors per article. These results underscore the potential of DGBL as a catalyst for advancing CT in vocational education and highlight the need for evidence-based game design guidelines, contextual field research, and interdisciplinary collaboration to optimize classroom implementation.

Keywords : *Digital Game-Based Learning, Computational Thinking, Vocational Education, Bibliometric, VOSviewer.*

INTRODUCTION

Digital Game-Based Learning (DGBL) is an educational approach that integrates digital game elements into the learning process to enhance students' motivation, engagement, and understanding of subject matter (Syahputra et al, 2024), (Velaora et al, 2022). This approach aligns with modern educational principles that emphasize active, experiential learning and the development of 21st-century skills such as critical thinking, collaboration, and problem-solving (Syahputra et al, 2024). DGBL functions not only as an entertainment medium but also as a learning tool that provides real-world contexts, immediate feedback, and challenges that stimulate strategic thinking (Esteban, 2024), (Syahputra et al, 2024). In vocational education, DGBL can simulate real work situations and reinforce students' technical skills (Dahalan, Alias & Shaharom, 2024). Through game characteristics such as clear objectives, rules, and reward systems, DGBL encourages exploration and self-directed learning (Syahputra et al, 2024). Thus, DGBL represents an innovative strategy that bridges the gap between theory and practice in vocational education settings.

The gap between theory and practice in vocational education often becomes a major obstacle in preparing students for the workforce (Kovalchuk et al, 2022). Much of the material taught theoretically is difficult to apply directly without adequate hands-on experience (Holly at al, 2021). Through DGBL, students can practice specific skills in simulations that closely mirror real industrial settings, making them more prepared and proficient when they enter the field (Lean et al, 2021). Moreover, DGBL helps develop students' computational thinking skills—such as problem analysis, problem solving, and logical, systematic decision-making (Ma et al, 2023). Strengthening these abilities is crucial, as computational skills are a key to success in the digital era and Industry 4.0.

Computational Thinking (CT) encompasses skills like problem solving, pattern recognition, abstraction, and algorithm design, which are essential to meet today's technological challenges (Hidayat et al, 2024). Research by Lu et al. (2023) shows that digital game-based learning significantly improves students' CT skills, with moderating effects depending on game type, intervention duration, and student culture. Additionally, a study by Pan et al. (2024) found that game-based learning can enhance CT competence, CT self-efficacy, and engagement among secondary school students. Similarly, Wu et al. (2024) confirmed that game-based learning boosts secondary students' CT competence, CT self-efficacy, and engagement during play. Therefore, implementing DGBL is an effective strategy for developing students' CT skills across educational levels.

In the field of education, DGBL and computational thinking are two complementary aspects that have garnered significant attention from educators. DGBL offers an interactive and enjoyable learning experience, thereby greatly enhancing student motivation and engagement (Nadeem, Oroszlanyova & Faraq, 2023). Meanwhile, computational thinking is a critical skill students need to meet the challenges of the digital world and solve problems systematically (Montiel and Gomez-Zermeño, 2021). Integrating the two enables the creation of learning methods that are not only enjoyable but also effective in honing critical and logical thinking abilities. Numerous studies support that the collaboration between DGBL and the development of computational thinking can strengthen learning outcomes and prepare students for the future workforce (Renganathan, Lakshminarayanan & Pathinathan, 2024), (Al Mahrouqi, 2023). However, understanding and research on both DGBL and computational thinking remain uneven and require further development.

Although research trends related to DGBL and computational thinking have been widely explored in various studies, comprehensive bibliometric analyses examining the impact of DGBL on students' computational thinking skills—particularly in vocational education—remain very limited.

This gap highlights the need to develop innovative methods and tools for managing and analyzing large, complex datasets in this field. Moreover, previous studies have not thoroughly investigated author collaborations, top publishing journals, or the latest publication trends related to DGBL and computational thinking. A deeper analysis would help provide a clearer picture of research directions and future collaboration opportunities. Therefore, focused bibliometric research is essential to support the advancement of knowledge and practice in this area.

Closing this gap requires a more in-depth and detailed bibliometric analysis to understand author collaboration patterns, influential journals, and publication trends related to DGBL and computational thinking. This study focuses on bibliometric analysis and a literature review in the context of the influence of DGBL on students' computational thinking skills, particularly in vocational education. To address the challenges of analyzing large and complex datasets, this study uses the R Studio programming language and employs VOSviewer for bibliometric mapping visualization. With this approach, it is expected that the research will provide a comprehensive overview that serves as a basis for evaluating and developing subsequent studies. Therefore, the results of this study will become an important reference for academics and practitioners in developing digital-based learning methods.

METHOD

This study employs the Systematic Literature Review (SLR) method to conduct a systematic and comprehensive examination of the literature (Van Dinter, Tekinerdogan & Catal, 2021). The focus of this research is an in-depth analysis of studies on the impact of Digital Game-Based Learning (DGBL) on students' computational thinking skills, particularly within vocational education settings. By using this approach, the study aims to provide a comprehensive overview of current trends and findings in the field. The review's results are expected to form a strong foundation for the development of future research and learning applications.

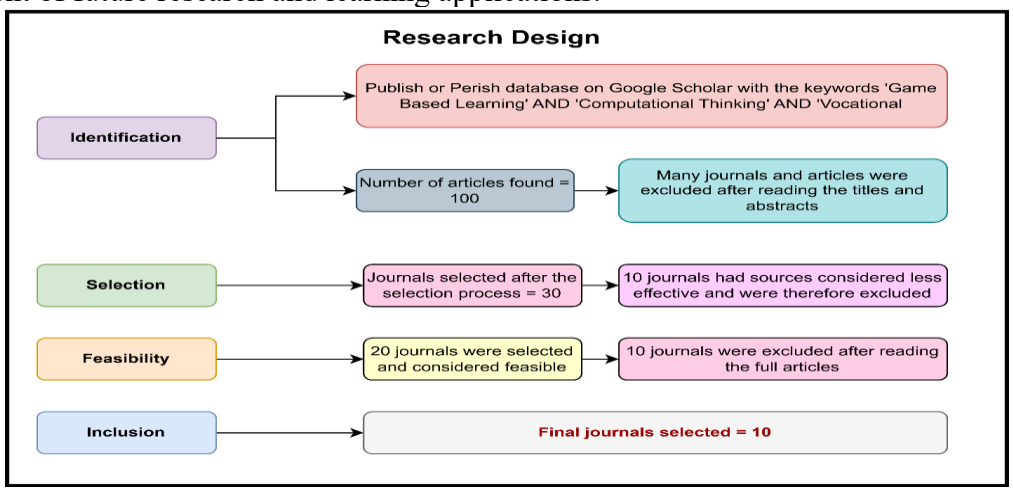


Figure 1. Research Design Flow

Figure 1 illustrates the research design flow using the Systematic Literature Review (SLR) method, which consists of four main stages: Identification, Selection, Feasibility, and Inclusion. In the Identification stage, the researcher searched for articles in the Publish or Perish database via Google Scholar using the keywords "Game Based Learning," "Computational Thinking," and "Vocational," yielding 100 articles. Next, in the Selection stage, articles deemed irrelevant were

removed based on their titles and abstracts, leaving 30 journals—of which 10 were later excluded for being less effective. In the Feasibility stage, 20 journals were assessed as meeting the criteria, but after full-text review, another 10 were found ineligible and removed. The final Inclusion stage resulted in 10 journals being selected for in-depth analysis in this study. This stepwise process ensures that the sources used are valid and relevant for producing reliable research findings.

Data processing in the bibliometric analysis of this study was carried out using mapping visualizations with VOSviewer version 1.6.20. The bibliometric analysis consists of four main stages: data retrieval with Publish or Perish 8, data processing using Microsoft Excel, data mapping with VOSviewer, and analysis of the resulting visualizations. Data exported from Publish or Perish are saved in both .csv and .ris formats. The .csv file is processed in Excel to extract information on the number of articles per year and to examine research patterns based on the selected keywords. Meanwhile, the .ris file is imported into VOSviewer for further mapping to visualize relationships among various research aspects. These visual maps are then analyzed to identify developments in the study of Digital Game-Based Learning's impact on students' computational thinking skills—particularly in vocational education—as well as to uncover research trends and the most frequently used terms, which will inform the design of future studies.

RESULTS AND DISCUSSIONS

1. Search Results Matrix

In the academic and scientific realm, citation frequency is the primary indicator used to measure a publication's quality, impact, and scholarly contribution within a field of study. The higher the citation count, the greater the recognition and relevance of the work among researchers. Citations reflect that a study is considered valuable and is being referenced by the scientific community. In this research, 100 articles relevant to the topics "Game Based Learning," "Computational Thinking," and "Vocational," published between 2016 and 2025, were retrieved. These articles have cumulatively received 15,801 citations, demonstrating that this topic attracts significant attention among academics and holds substantial potential for further development in future studies.

Table 1. Citation Metrics

Paper	100
Citations	15.801
Cites/year	1755.67
Cites/paper	158.01
Authors/paper	3.13
h-index	73
g-index	100

Based on the bibliometric analysis presented in Table 1 of the 100 reviewed scientific articles, the total citation count is 15,801. This indicates that these articles hold a high level of relevance and impact within the academic community. The average number of citations per year is 1,755.67, while the average citations per article is 158.01, reflecting each work's significant contribution to knowledge development in the studied topic. Each article was authored by an average of 23.13 authors, suggesting substantial scientific collaboration, even if team sizes are not exceedingly large. An h-index of 73 reveals that 73 articles have each been cited at least 73 times, and a g-index of 100 signifies that the top 100 articles have amassed strong cumulative citations, further solidifying their

role as key references in the fields of Game-Based Learning, Computational Thinking, and Vocational Education.

Table 2. 10 Articles With The Highest Number Of Citations

No	Number of Citations	Authors	Title	Year	Source
1	2183	D Weintrop, at al.	Defining computational thinking for mathematics and science classrooms [21]	2016	Journal of Science Education and Technology
2	1696	VJ Shute, C Sun, J Asbell-Clarke	Demystifying computational thinking [22]	2017	Educational research review
3	438	F Buitrago Flórez, at al.	Changing a generation's way of thinking: Teaching computational thinking through programming [23]	2017	Review of Educational Research
4	395	CP Brackmann, at al.	Development of computational thinking skills through unplugged activities in primary school [24]	2017	WiPSCE '17: Proceedings of the 12th Workshop on Primary and Secondary Computing Education
5	382	J Leonard, at al.	Using robotics and game design to enhance children's self-efficacy, STEM attitudes, and computationa	2016	Journal of Science Education and Technology

			l thinking skills [25]		
6	356	J Lockwood, A Mooney	Computational thinking in education: Where does it fit? A systematic literary review [26]	2017	arXiv
7	318	S Papadakis, at al.	Developing fundamental programming concepts and computational thinking with ScratchJr in preschool education: a case study [27]	2016	International Journal of Mobile Learning and Organisation
8	311	S Bocconi, at al.	Developing computational thinking in compulsory education [28]	2016	The Joint Research Centre (JRC)
9	298	M Bower,at al.	Improving the computational thinking pedagogical capabilities of school teachers [29]	2017	Australian Journal of Teacher Education
10	268	V Dagiene, G Stupuriene	Bebras--A Sustainable Community Building Model for the Concept Based Learning of	2016	Informatics in education

			Informatics and Computational Thinking [30]

Table 2 presents the top ten most cited scholarly articles related to Game-Based Learning, Computational Thinking, and Vocational Education between 2016 and 2025. The article with the highest number of citations (2,183 citations) is the work of D. Weintrop et al., titled "Defining Computational Thinking for Mathematics and Science Classrooms," published in 2016 in the Journal of Science Education and Technology. All the articles listed have made a significant impact in their respective fields, as evidenced by their high citation counts, and most were published in reputable journals such as Educational Research Review, Review of Educational Research, and other international journals and conference proceedings. These articles generally focus on the development of computational thinking skills through education, the use of technology, unplugged activities, and game-based or robotics-based approaches across various educational levels.

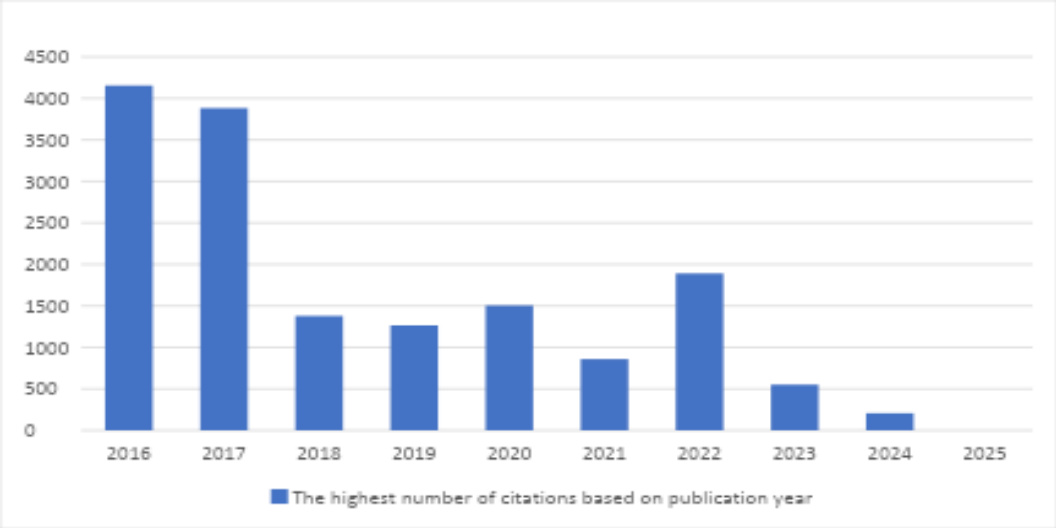


Figure 2. The Highest Number Of Citations Based On Publication Year

Figure 2 shows the highest citation counts based on the publication year of the articles analyzed in this study. It can be seen that the year 2016 recorded the highest number of citations, with more than 4,000 citations, followed by 2017 with around 3,900 citations. After these years, the citation counts experienced a significant decline, although there were slight increases in 2020 and 2022, with approximately 1,500 and 1,800 citations respectively. Subsequent years, such as 2021, 2023, and especially 2024, show lower citation trends, likely due to the newer publication dates, resulting in fewer citations so far. This graph indicates that articles published in the early years (particularly 2016 and 2017) have had the greatest impact and broadest influence on the development of studies concerning Game Based Learning, Computational Thinking, and Vocational Education.

2. Publication Trend Analysis

The trend of scientific publications discussing the influence of Digital Game-Based Learning (DGBL) on the development of students' computational thinking, particularly in the context of vocational education, shows a positive growth year by year. This is illustrated in Figure 3, which presents the number of publications indexed in Google Scholar during the period from 2016 to 2025.

Overall, the number of studies published on this topic tends to increase, reflecting the growing interest from the academic community. The peak of publications occurred in 2022 with a total of 17 articles, followed by 2020 with 14 publications, and both 2018 and 2021 with 13 publications each. The trend began in 2016 with 11 publications and slightly declined in 2017 with 10 publications. Although there was a decrease in 2023 with only 7 publications and a further drop in 2024 with 2 publications, the overall trend indicates that the topic of DGBL and computational thinking in vocational education has become a relevant and continually developing field of study within the international scientific community.

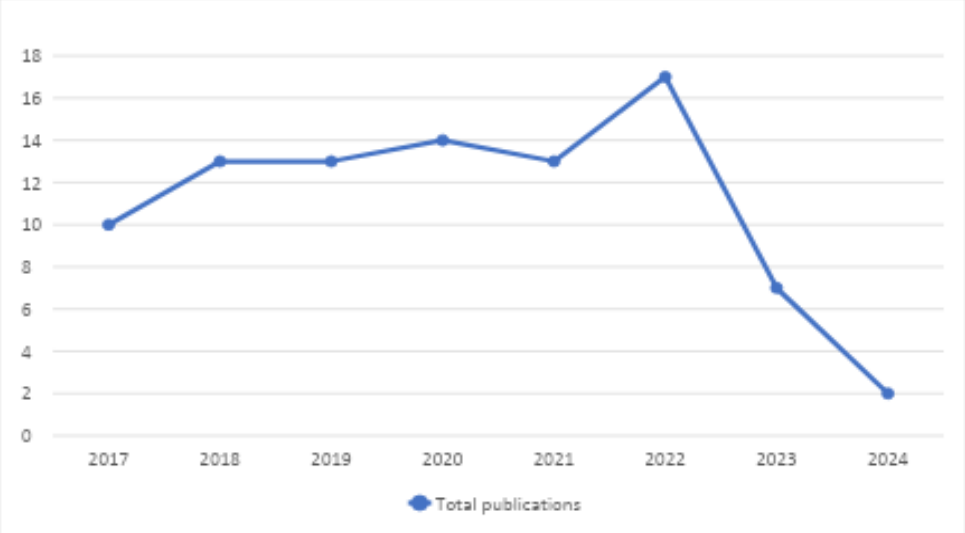


Figure 3. Total Publications by Year

3. Keyword Trend Analysis

Co-word analysis is a highly useful approach for exploring and understanding the relationships between keywords that frequently appear together in various scientific publications. This method not only provides a comprehensive overview of the direction and focus of research within a field but also reveals patterns of connections between overlapping topics. In the context of studying the influence of Digital Game-Based Learning (DGBL) on Computational Thinking (CT) abilities, the analysis process begins with collecting keyword data from relevant articles sourced from scientific databases such as Scopus, Web of Science, or Google Scholar. After gathering the data, a co-word matrix is constructed to show how often pairs of specific keywords co-occur within the same articles. For example, if the keyword "Digital Game-Based Learning" frequently appears alongside "Computational Thinking," this relationship will be clearly visible in the matrix, indicating a strong link between the topics. The next stage involves statistical analysis and data visualization using software such as VOSviewer or Gephi. These visualizations assist researchers in identifying keyword clusters, uncovering the main topics dominating the research, and recognizing subtopics that often appear together, thereby providing more focused guidance for future research development.

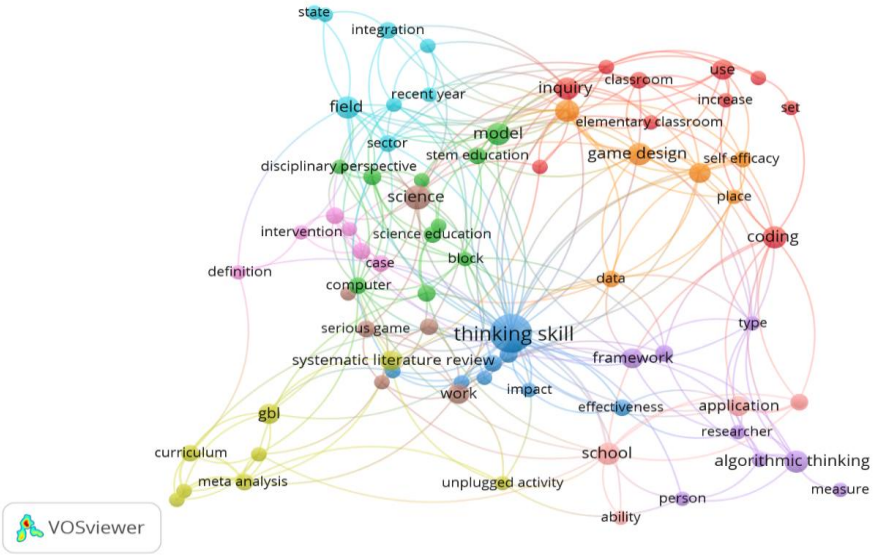


Figure 4. Co-Word Network Visualization

The visualization of the co-word analysis results using VOSviewer reveals the main research trends related to the development of thinking skills, particularly through the Digital Game-Based Learning (DGBL) approach. The keyword "thinking skill" appears as the central node connecting various topics, linked to terms such as "game design," "algorithmic thinking," "coding," "inquiry," and "school," reflecting a research focus on enhancing thinking abilities through educational games across different educational levels. Different colored clusters highlight sub-themes such as the application of DGBL in elementary schools, the development and measurement of algorithmic thinking skills, and the integration of learning within STEM and science education contexts. Terms like "serious game," "unplugged activity," and "framework" further emphasize that this approach is not limited to formal education but is also incorporated into various innovative educational strategies. Overall, this visualization illustrates that the use of educational games to foster Computational Thinking skills is a growing trend receiving widespread attention across multiple education-related research fields.

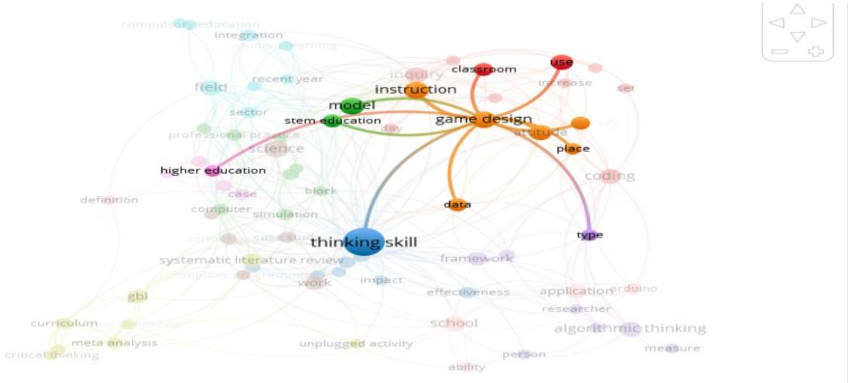


Figure 5. Visualization of the Connection Map Between Game Design and Computational Thinking Skills

Based on the co-word visualization map in Figure 5, there is a strong and direct connection between the keywords *game design* and *thinking skill*, indicated by a thick line linking them.

This suggests that in the analyzed literature, game design is frequently associated with the development of thinking skills, both in educational and training contexts. Game design functions not only as a form of entertainment but also as a pedagogical approach that stimulates critical, creative, and systematic thinking processes. Through the design of educational games, learners are encouraged to solve problems, make decisions, and apply logic and strategy—activities that directly support the enhancement of thinking skills. Additionally, the connection between game design and other keywords such as *instruction*, *data*, and *coding* further emphasizes that game design is integrated within a deep, technology-based learning approach aimed at sharpening students' thinking abilities.

The results of this co-word analysis carry significant implications for research and educational practice, particularly in the development of thinking skills through game design-based approaches. The strong and direct link between game design and thinking skills indicates that game-based learning is not only relevant but also strategic in shaping students' critical, creative, and reflective thinking processes. Practically, educators and curriculum developers should consider integrating game design into teaching methods to enhance student engagement and learning outcomes. Furthermore, the connections with other keywords such as instruction, model, data, and algorithmic thinking suggest that this approach can be combined with systematic, data-driven instructional design and aligns well with current trends in digital and computational literacy. From a research perspective, these findings open opportunities for further exploration on how specific elements of game design can facilitate the development of particular thinking skills, such as logical, strategic, and evaluative thinking. Thus, this analysis not only maps keyword relationships but also provides strategic guidance for innovation in technology- and game-based education.

CONCLUSIONS

This co-word analysis reveals that game design is not merely an alternative approach in learning, but has the potential to become a key catalyst in developing students' thinking skills, especially in the digital era. The strong direct relationship between game design and thinking skills indicates that elements of game design—such as challenges, rewards, and problem-solving—create a learning environment capable of stimulating complex cognitive processes. However, this relationship does not occur automatically; it is highly influenced by the quality of the game design, the context of its implementation, and comprehensive pedagogical integration. In other words, game design holds significant pedagogical potential, but this can only be optimally realized if it is based on a strong theoretical foundation and positioned as part of a broader, holistic learning system. These findings also critique the conventional approaches still dominating educational practice and challenge educators to be more adaptive to evidence-based innovations.

To enhance the effectiveness of integrating game design in computational thinking learning, the first step is to develop evidence-based game design guidelines that explicitly link game mechanics with thinking skill indicators, so that each element—from difficulty level to feedback patterns—is designed to train specific cognitive processes. Furthermore, it is recommended to conduct contextual and longitudinal field research in vocational or technical classroom settings, with pre- and post-measurements and long-term evaluation to ensure skill transfer from game environments to real-world situations. Interdisciplinary collaboration among educators, instructional design experts, and software developers is also crucial to ensure that technological solutions align with curricula and industry needs. At the implementation level, teachers need intensive training and mentoring in

selecting, adapting, and evaluating serious games in the classroom, including strategies for assessing students' progress in computational thinking. Finally, each institution should implement a comprehensive evaluation framework that includes engagement metrics, difficulty adaptation, and long-term impact, so that the application of Digital Game-Based Learning can be effectively scaled across various educational levels and disciplines.

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