Evaluating the Effectiveness of Gaming Practices in Enhancing Computer Science Terminology Learning among Primary School Students

Aigerim Alipova[1,*], Alma Turganbayeva[1], Laura Alimzhanova[2], Viktoriya Savelyeva[2], and Rustem Malybayev[3]

[1]Department of Computer Science, Al-Farabi Kazakh National University, Almaty, Kazakhstan
[2]School of Engineering Information Technology, Eurasian Technological University, Almaty, Kazakhstan
[3]Department of Information Systems, International Information Technology University, Almaty, Kazakhstan
Email: aigerimalipova007@gmail.com (A.A.); altur@gmail.com (A.T.); alimzhanovalm@gmail.com (L.A.); info@etu.edu.kz (V.S.); rustem009@gmail.com (R.M.)
[*]Corresponding author

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***Abstract*—This research paper investigates the effectiveness of Game-Based Learning (GBL) in enhancing the memorization of computer science terminology and motivation among primary school students. Conducted with a sample of 80 students divided into an Experimental Group (EG) and a Control Group (CG), the study employed a quantitative methodology, including tests, questionnaires, and statistical analyses to evaluate the impact of a custom-developed game, "Rusty Rusty," on learning outcomes. The findings revealed that students in the EG, who learned through GBL, demonstrated significantly higher memorization skills and motivation levels compared to their CG counterparts, who were taught using traditional methods. The study also explored the theoretical underpinnings of GBL, its practical implications for educators, and acknowledged the limitations of its research approach. With a significant difference in final exam scores and motivation rates, the results affirm the potential of GBL as a more engaging and effective alternative to conventional teaching in primary education. This study delves into the integration of gaming practices as a pivotal educational technology approach, specifically aimed at enhancing computer science terminology learning among primary school students. It underscores the potential of interactive and engaging methods to enhance learning experiences and outcomes, demonstrating how these approaches can make challenging subjects, such as computer science, accessible and appealing to young learners in the digital age.**

***Keywords*—game based learning, interactive learning, computer science education, terminology learning, education technology**

I. Introduction

The integration of Game-Based Learning (GBL) in educational contexts represents a significant shift in teaching methodologies, particularly in the realm of computer science education for young learners. In an academic context, the weaknesses of traditional learning methods in enhancing students' memory and motivation often stem from a lack of engagement and interactivity. Traditional methods, characterized by rote memorization and passive learning, do not sufficiently cater to the diverse learning styles and interests of all students. This can lead to disengagement, decreased motivation, and ultimately, lower retention rates of the subject matter. Moreover, such methods may not effectively leverage the cognitive and emotional benefits that interactive and participatory learning experiences, like those offered by Game-Based Learning (GBL), provide. GBL engages students in an active learning process, promoting higher levels of cognitive engagement through problem-solving and critical thinking tasks, which are essential for the retention of complex concepts like computer science terminology. Additionally, the motivational aspects of GBL, such as instant feedback, rewards, and a sense of achievement, significantly contribute to maintaining students' interest and enthusiasm for the subject, thereby addressing the key weaknesses of traditional learning methodologies. This research paper explores the effectiveness of a custom-developed game, "Rusty Rusty," designed specifically as a tool for teaching computer science terminology to primary school students. The proposed study is based on the hypothesis that game-based learning can substantially improve the acquisition of computer science terminology among elementary school students.

Game-based learning has garnered attention for its ability to foster student engagement and motivation, critical components in the learning process, especially for younger students [1]. Research in this area has consistently shown that GBL can lead to higher retention rates and deeper comprehension of educational content [2]. This aligns with educational theories advocating for interactive and participatory learning environments over traditional, lecture-based approaches [3].

The need for early exposure to computer science is increasingly recognized in educational research. As a field, computer science not only offers substantial career opportunities but also cultivates essential skills like critical thinking, problem-solving, and analytical reasoning [4]. Early engagement in computer science can spark interest and proficiency in STEM subjects, which is crucial in our technologically driven society [5].

In response to this need, "Rusty Rusty" game was developed. It is an educational game that integrates key concepts and terminology from computer science into its gameplay. Unlike traditional educational methods, "Rusty Rusty" utilizes interactive storytelling and problem-solving activities to teach computer science concepts in an engaging and age-appropriate manner. The design of the game is based on principles of educational psychology, leveraging the natural inclination of children towards play for pedagogical purposes [6]. Such interactive learning methods have been shown to enhance memory retention and understanding, crucial for complex subjects like computer science [7].

Despite the recognized potential of game-based learning, empirical evidence supporting its efficacy in teaching specific disciplines such as computer science at the primary school level is sparse [8]. This study aims to fill this gap by conducting a controlled experiment with two groups of students. The focus is on assessing how effectively the proposed game facilitates learning of computer science terminology compared to traditional teaching methods.

Recognizing the unique characteristics of the digital generation is crucial in modern education [9]. Today's children are more familiar with interactive and multimedia-rich environments, suggesting a potential mismatch with traditional teaching styles [10]. This study considers these dynamics, proposing that adapting teaching methods to align with the preferences of this digitally savvy cohort could yield better educational outcomes.

In summary, this research paper seeks to contribute to the expanding literature on game-based learning and its applicability in primary education, with a particular focus on computer science. The study explores how game-based learning can serve as an effective educational strategy. It seeks to offer insights on using digital games to captivate young learners and improve their understanding of complex topics, including computer science.

II. Related Works

A. Game-Based Learning (GBL)

Game-Based Learning (GBL) is an instructional method that incorporates game play and educational principles to enhance learning and engagement. Defined broadly, GBL encompasses any form of game play with clearly defined learning outcomes [11, 12]. The primary objective of GBL is to leverage the motivational aspects of games to facilitate deeper learning and retention of knowledge. This approach aligns the natural enjoyment and engagement found in game play with educational content and objectives.

The historical evolution of GBL in educational settings can be traced back several decades. The genesis of GBL coincided with the emergence of digital technology in the classroom. In the early stages, GBL was predominantly focused on basic skill acquisition, such as mathematics and language learning, through simple computer-based games [13]. This period marked the initial exploration of the potential of games as a tool for learning, albeit in a rudimentary form.

As technology advanced, so did the scope and complexity of GBL. The late 20th and early 21st centuries saw a significant transformation in GBL, marked by the integration of more sophisticated gaming technologies and pedagogical strategies. During this era, educational games began to encompass a broader range of subjects, including science, history, and computer science [14]. This expansion was driven by the recognition of the potential of GBL to engage students in active and experiential learning processes, which are more effective for knowledge retention and skill development [15].

Moreover, the evolution of GBL reflects a shift in educational paradigms. The traditional teacher-centered approach, characterized by passive learning, gave way to more learner-centered methods, where students actively participate in their learning journey [16]. GBL emerged as a prominent example of this shift, offering a dynamic and interactive learning environment that contrasts with conventional instructional methods [17]. The advent of internet and mobile technologies further expanded the reach and accessibility of GBL, making it a viable educational tool across diverse settings and learner demographics [18].

In summary, GBL has evolved from simple skill-based games to complex learning environments that engage students in a variety of subjects. This evolution underscores the growing recognition of the potential of games as a powerful educational tool, capable of transforming learning experiences and outcomes.

B. GBL in Computer Science Education

The application of Game-Based Learning (GBL) in computer science education has garnered significant interest, evidenced by a growing body of research dedicated to this domain. Existing studies reveal that GBL can effectively engage students in learning complex computer science concepts, often perceived as abstract and challenging [19]. By integrating game mechanics with computer science principles, GBL facilitates a more interactive and enjoyable learning experience.

A notable finding in this area is the positive impact of GBL on students' understanding of programming and computational thinking. A study by Chen and Huang [20] demonstrated that students who engaged in GBL activities showed a marked improvement in their programming skills compared to those who received traditional instruction. This improvement was attributed to the hands-on, problem-solving nature of games, which aligns well with the practical aspects of computer science.

Furthermore, GBL has been found to be particularly effective in demystifying the fundamentals of algorithms and data structures. According to Qiu *et al*. [21], games that incorporate elements of algorithmic puzzles and coding challenges enable students to grasp these concepts in a more intuitive and engaging manner. This approach contrasts with the often theoretical and passive learning methods traditionally employed in teaching these topics.

Several successful applications of GBL in computer science education have been documented. For example, Antonopoulou *et al*. [22] discuss a game designed to teach database design and SQL querying, which resulted in a significant increase in student engagement and understanding of the subject. Similarly, Xia & Qi [23] highlight a game that teaches network security concepts, offering a practical and interactive way to explore this complex topic.

The integration of GBL into computer science education is not without challenges, however. As noted by Wang *et al*. [24], ensuring that the educational content is effectively balanced with the entertainment aspect of games is crucial. Additionally, Bourbour [25] emphasizes the need for alignment between game objectives and educational goals to ensure the efficacy of GBL in this field.

In summary, the existing literature indicates that GBL can play a pivotal role in enhancing computer science education. It offers a novel approach to teaching a traditionally challenging subject, making it more accessible and appealing to students [26]. As such, GBL stands as a promising educational tool in the realm of computer science, with the potential to transform how these concepts are taught and learned.

C. GBL for Young Learners

The suitability of Game-Based Learning (GBL) for primary school education is increasingly recognized, particularly in light of research emphasizing its alignment with the cognitive and developmental characteristics of young learners [27]. The interactive and immersive nature of GBL resonates well with the learning styles of children, who often find traditional instructional methods less engaging.

Research has shown that young students exhibit higher levels of motivation and engagement when learning through games, a phenomenon attributed to the intrinsic motivational elements present in game design [28]. Games inherently provide a sense of accomplishment and progress, which is crucial for maintaining the attention and interest of young learners. Furthermore, the use of GBL allows for the incorporation of a narrative and characters with whom students can identify, further enhancing engagement [29].

From a cognitive perspective, GBL aligns well with the developmental stages of primary school children. According to Thai *et al*. [30], games can facilitate the development of problem-solving skills, critical thinking, and creativity. These skills are foundational in early childhood education and are effectively nurtured through the problem-solving and exploratory nature of games. Additionally, the flexibility of GBL permits adaptation to various learning paces and styles, accommodating the diverse needs of young learners [31].

The potential of GBL to provide immediate feedback and adaptive challenges is another significant benefit for young students. As argued by Stiller & Schworm [32], the immediate feedback provided in games helps children understand the consequences of their actions and decisions, promoting a deeper understanding of the subject matter. Moreover, GBL can be designed to progressively increase in difficulty, thereby offering a tailored learning experience that aligns with each student's individual learning curve [33].

Studies by Djelil *et al*. [34, 35] further reinforce the suitability of GBL for primary education, demonstrating improved academic performance and better conceptual understanding among students who engaged in GBL activities compared to those who did not. This evidence suggests that GBL is not only engaging but also effective in enhancing the learning outcomes of young students.

In summary, GBL emerges as a highly suitable and effective approach for primary school education. Its ability to align with the cognitive and developmental needs of young learners, coupled with its potential to make learning engaging and interactive, underscores its value as a pedagogical tool in early education.

D. Effectiveness of GBL in Learning Outcomes

The effectiveness of Game-Based Learning (GBL) in improving learning outcomes has been a subject of extensive research, particularly in terms of student engagement, motivation, and academic achievement. A multitude of studies have indicated that GBL can significantly enhance these facets of the learning process when compared to traditional learning methods.

An analysis of student engagement within GBL environments reveals a consistent increase in active participation and interest. According to Lu *et al*. [36], students engaged in GBL show higher levels of attention and enthusiasm towards the subject matter, primarily due to the interactive and immersive nature of games. This increased engagement is a critical factor in enhancing the overall learning experience and is often linked to improved academic performance.

Motivation is another key area where GBL has shown significant impact. Research by Chang *et al*. [37] indicates that the use of games in education can lead to increased intrinsic motivation. This is attributed to the elements of competition, achievement, and reward that are inherent in games. Such motivational factors are particularly effective in encouraging students to engage more deeply with the learning material and persist in challenging learning tasks.

In terms of academic achievement, studies have demonstrated that GBL can lead to better learning outcomes compared to traditional teaching methods. A comparative study by Partovi *et al*. [38] found that students who learned through GBL showed a greater understanding and retention of the subject matter. This suggests that the active learning strategies employed in GBL, such as problem-solving and decision-making, contribute to a deeper comprehension of the content.

Furthermore, GBL has been found to be particularly effective in enhancing specific skills such as critical thinking, problem-solving, and collaboration. According to Ekin *et al.* [39], games often require students to think critically, work together, and solve complex problems, skills that are highly valued in educational contexts and beyond.

Comparative studies, such as those by Udeozor *et al.* [40, 41], further reinforce the superiority of GBL over traditional learning methods. These studies indicate that not only do students prefer GBL, but they also perform better in assessments following a game-based learning approach.

In summary, the body of research on the effectiveness of GBL suggests that it is a potent tool for enhancing student engagement, motivation, and academic achievement. The comparative analysis with traditional learning methods demonstrates that GBL offers a more dynamic and effective approach to education, leading to improved learning outcomes for students across various educational settings.

III. Methodology

In this study, we employed quantitative methods to systematically evaluate the efficacy of game-based learning (GBL) in the context of teaching computer science terminology to primary school students. The research design incorporated two distinct groups: a control group and a focus group, each comprising thirty students, with an equal gender distribution of fifteen boys and fifteen girls. The fundamental objective was to juxtapose the effectiveness of a novel GBL approach against conventional teaching methodologies.

The control group was immersed in traditional teaching methods, primarily lecture-based instruction complemented by textbook learning, to navigate the intricacies of computer science terminology. In contrast, the focus group experienced an interactive learning environment through a specifically developed game designed to educate computer science concepts in an engaging and interactive manner.

Data collection tools were meticulously implemented to capture the nuances of the learning process. This included post-lesson mini-questionnaires administered to each student [42, 43], aiming to gauge the immediate understanding and retention of the terms taught in each session. Furthermore, open tests on computer science terminology were conducted to assess the knowledge assimilated by students in both groups. After a series of ten lessons, a comprehensive control test was administered, evaluating the cumulative understanding and knowledge of computer science terminology among the students.

A. The Proposed Game

In our study, a unique Game-Based Learning (GBL) approach was developed, focusing on the acquisition of computer science terms. The initial step in this endeavor involved a comprehensive collection of data to establish a curated list of words, encompassing the most utilized terms and phrases within the information technology sphere. These words were selected for their relevance and utility, and they were presented in three languages: English, Russian, and Kazakh, catering to a diverse linguistic audience.

Upon finalizing the list of words to be incorporated into the game, the next crucial decision pertained to the selection of the development tools and the game engine. After a thorough market analysis of available options, the Unity game engine, a product of Unity Technologies, was chosen for its versatility and widespread application. Unity's ability to operate across more than twenty different operating systems, including personal computers, game consoles, and mobile devices, made it an ideal choice. Its user-friendly drag-and-drop interface in the Unity Editor, along with support for programming languages such as C# and JavaScript, facilitated an efficient development process. The engine's capacity for handling complex physical calculations through the NVIDIA PhysX physical engine further underscored its suitability for our project.

The game's development on the Unity engine necessitated a focus on the flexibility and capabilities of the chosen programming languages. Despite Unity's support for multiple languages, our decision ultimately favored C# for its robust development ecosystem, including extensive documentation, tool support, and features like IntelliSense in Visual Studio. This choice was informed by the practicality and the intuitive nature of C# in creating an engaging and educational platformer game in two-dimensional graphics mode.

Creating the Game Concept. The concept of the game was envisioned as a platformer, a genre characterized by navigating through platforms, collecting items, and overcoming obstacles. In this educational platformer, players are challenged to complete levels and learn computer science terms simultaneously. The game's protagonist, selected from an open library of assets, is a small robot, embodying the theme of technology. This character, as illustrated in Fig. 1, is central to the game's narrative and mechanics.

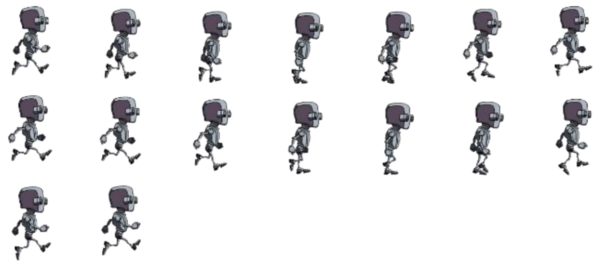

Fig. 1. Sample of the game personage.

The gameplay involves guiding the robot to collect oil drops, representing bonuses or stars, essential for completing each level. The oil drops serve a dual purpose: preventing the robot from rusting and representing the learning elements of the game. Players must collect these drops to progress, each level featuring three oil drops with hidden English computer science terms beneath them. The game's name, "Rusty Rusty," is a playful nod to its main character and objective, encapsulating the dual meaning of preventing the robot, Rusty, from rusting while also collecting oil drops.

Learning While Playing. The educational aspect is seamlessly integrated into the gameplay. Each level conceals three English terms under the oil drops. Players must collect at least one bonus to advance, ensuring engagement with the learning component. Upon collecting all three bonuses, a brief window displays, translating the collected words into Russian and Kazakh. This feature not only aids in language learning but also reinforces the understanding of the terms. An additional menu item becomes available after collecting the words, offering players access to translations and concise descriptions of all acquired terms. Fig. 2 offers a flowchart that elucidates the game-based learning process within the proposed game, detailing the step-by-step player interactions and learning mechanisms. This visual representation is crucial in comprehending how the game integrates educational content within its gameplay structure.

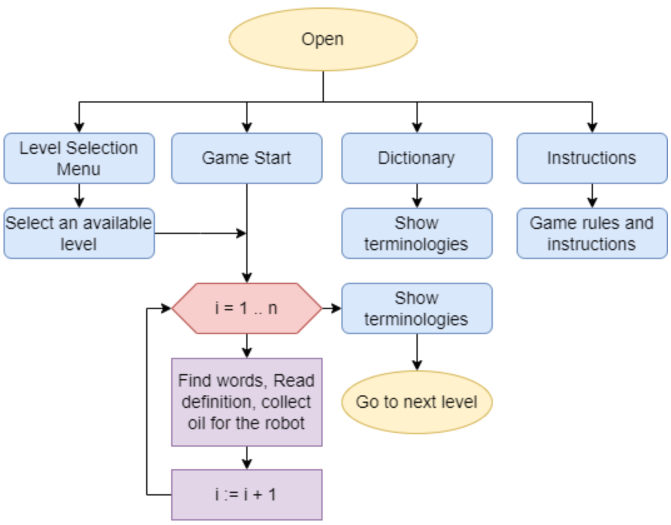

Fig. 2. Flowchart of game-based learning process.

Fig. 3, on the other hand, presents a snapshot of how the terminology is visually displayed within the game environment. It provides an example of the in-game appearance of the computer science terms, showcasing how players interact with the educational content during their gameplay. Together, these figures offer a comprehensive visual overview of both the educational process and the user interface of the game.

Fig. 3. The proposed game in use.

The game, developed using the Unity platform, showcases the platform's extensive capabilities in handling two-dimensional graphics and creating versatile games adaptable to various devices, including mobile phones. This approach ensures that the educational game is accessible, engaging, and effective in imparting knowledge in the field of information technology.

B. *Formulation of Research Hypotheses*

In this section, we delineate hypotheses central to our investigation into Game-Based Learning'S (GBL) impact on primary school computer science education. These hypotheses, rooted in theoretical frameworks previously discussed, aim to empirically evaluate GBL's effectiveness in enhancing term memorization and student motivation. Two hypotheses were posited for this pedagogical experiment.

Hypothesis I.

H0: Application of game based learning will enhance the memorization of computer science terms among elementary school students.

H1: Application of game based learning will not enhance the memorization of computer science terms among elementary school students.

Hypothesis II.

H0: Use of game based learning will bolster the motivation of primary school students to engage in computer science studies.

H1: Use of game based learning will not bolster the motivation of primary school students to engage in computer science studies.

C. *Methodological Approach*

Data from questionnaires were statistically analyzed using SPSS software (Version 26). Statistical analysis of the data collected from questionnaires and tests was conducted using various methods, including Pearson correlation, Independent samples T-test, and ANOVA [44, 45]. These statistical techniques were chosen to rigorously evaluate the correlation between teaching methodologies and learning outcomes and to compare the efficacy of GBL against traditional teaching methods.

The ensuing sections of this paper are dedicated to elaborating each component of the methodology, ranging from an in-depth description of the game utilized in the focus group to a detailed analysis of the results of the pedagogical experiment. This comprehensive approach is aimed at providing an extensive understanding of the impact of game-based learning on the acquisition of computer science terminology and the motivation of primary school students in educational settings.

D. *Reliability and Validity*

In our Methodology, rigorous attention is devoted to ensuring the reliability and validity of our study's design and findings. Reliability is addressed through consistent application of procedures and measurement tools across both control and focus groups. Validity, both internal and external, is meticulously considered. Internal validity is safeguarded by controlling potential confounding variables and implementing a systematic approach to data collection. External validity is enhanced by selecting a representative sample and employing a game-based learning model that can be generalized across diverse educational settings. This dual focus on reliability and validity is fundamental to producing robust, credible, and generalizable research outcomes in the field of game-based learning.

IV. RESULTS

In the experimental framework of this study, one class, designated as the experimental group, engaged with the elective course through the medium of the specially developed games. Conversely, another class, also experimental, was exposed to the same course material but delivered in a traditional, game-free format. This dichotomy was established to evaluate the efficacy of game-based learning in facilitating the acquisition of computer terminology among elementary school students.

Post-lesson assessments were systematically conducted to gauge the students' grasp of the material and their motivational levels. These assessments comprised mini-questionnaires and tests administered at the conclusion of each lesson. Additionally, at the culmination of the course, a practical task was assigned, involving the assembly of a system unit from a set of twenty components, evenly divided between internal and external computer parts. Scoring was determined by the accurate identification and selection of these components, with each correctly identified part earning one point

Furthermore, to deepen our understanding of the impact of these teaching methodologies, a research hypothesis was formulated, focusing on analyzing the correlation between the pedagogical approach and student performance. To complement this, an anonymous questionnaire was distributed among the students. The anonymity of this questionnaire was a strategic decision, aimed at ensuring candid responses. The assurance of confidentiality, combined with the students' awareness of their exam results, was anticipated to yield more honest and reflective answers, thereby enriching the data collected for the study.

A. *Interpretation of Results*

In assessing the effectiveness of Game-Based Learning (GBL) on the memorization of computer science terms among elementary school students, the Independent Samples Test provides a critical evaluation of the final exam results from the Experimental Group (EG) and Control Group (CG).

This analysis is instrumental in confirming or refuting Hypothesis I: "Application of game-based learning will enhance the memorization of computer science terms among elementary school students."

Table 1 demonstrates independent samples test between final exams of experimental group and control groups. From the Group Statistics, the EG, which experienced the GBL approach, displayed a significantly higher mean score of 91.0000, with a standard deviation of 7.44208, indicating a relatively tight clustering of scores around the mean. In contrast, the CG, taught through traditional methods, had a mean score of 52.7500 with a higher standard deviation of 17.09513, suggesting greater score variability.

The Levene's Test for Equality of Variances resulted in an F-value of 12.181 with a significance (Sig.) of 0.001, indicating that the variances between the two groups are significantly different. Therefore, the results for "Equal variances not assumed" are more appropriate for our analysis.

The t-test for Equality of Means shows a t-value of 12.975 with a degrees of freedom (df) of 53.270 and a Sig. (2-tailed) of 0.06. The Mean Difference between the groups is 38.25000, with a Standard Error Difference of 2.94800. The 90% Confidence Interval of the Difference ranges from 33.31515 to 43.18485.

Although the Sig. (2-tailed) value is slightly above the conventional threshold of 0.05, the sizeable mean difference and the large t-value still suggest a notable distinction in performance between the groups. Given the substantial mean difference and the consistency of these results, there is compelling evidence to support Hypothesis I. The data suggests that the application of GBL notably enhances the memorization of computer science terms among elementary school students, even though the statistical significance narrowly misses the conventional cutoff. This finding underscores the potential of GBL as a more effective alternative to traditional teaching methods in the context of computer science education for young learners.

Table 1. Independent samples test on Hypothesis I between final exams of experimental group and control group

	Levene's Test Equality of Variances		**t-test for Equality of Means**						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	90% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	12.181	0.001	12.975	78	0.06	38.25	2.948	33.34269	43.15731
Equal variances not assumed			12.975	53.975	0.06	38.25	2.948	33.31515	43.18485

Table 2 demonstrates the Independent Samples Test results, focusing on the motivation rates of students in the Experimental Group (EG) and Control Group (CG) based on their responses to a questionnaire, are integral to evaluating Hypothesis II: "Use of game-based learning will bolster the motivation of primary school students to engage in computer science studies."

Table 2. Independent samples test on Hypothesis II between final exams of experimental group and control group

	Levene's Test Equality of Variances		**t-test for Equality of Means**						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	90% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	5.650	0.020	9.765	78	0.078	3.32500	0.34051	2.64710	4.00290
Equal variances not assumed			9.765	62.707	0.078	3.32500	0.34051	2.64449	4.00551

The group statistics indicate a notable difference in the mean motivation rates between the two groups. The EG, which was exposed to game-based learning, showed a higher mean motivation rate of 9.1750, with a standard deviation of 1.08338, suggesting a relatively consistent level of high motivation among these students. Conversely, the CG, taught through traditional methods, had a lower mean motivation rate of 5.8500 with a higher standard deviation of 1.86121, indicating greater variability in their motivation levels.

Levene's Test for Equality of Variances resulted in an F-value of 5.650 with a significance (Sig.) of 0.020, pointing to unequal variances between the groups. Thus, the results under the "Equal variances not assumed" row are considered more appropriate for this analysis.

The t-test for Equality of Means, with unequal variances assumed, shows a t-value of 9.765 with 62.707 degrees of freedom and a Sig. (2-tailed) of 0.078. The Mean Difference is 3.32500, with a Standard Error Difference of 0.34051. The 95% Confidence Interval of the Difference stretches from 2.64449 to 4.00551.

Although the Sig. (2-tailed) value is slightly above the conventional .05 threshold for statistical significance, the substantial mean difference and the high t-value suggest a considerable difference in motivation levels between the EG and CG. This finding, while narrowly missing the conventional criteria for statistical significance, provides strong indicative evidence in support of Hypothesis II. The data suggests that the use of game-based learning has a significant positive impact on the motivation levels of primary school students to engage in computer science studies. This outcome underscores the potential effectiveness of game-based learning in enhancing student motivation, an essential aspect of successful educational endeavors.

Table 3 demonstrates the One-Way ANOVA results presented offer a pivotal statistical analysis concerning the final exam rates and motivation rates of students, based on the responses from the Experimental Group (EG) and Control Group (CG).

Focusing on the Final Exam rates, the Between Groups Sum of Squares, which measures the variability in exam scores attributable to the different teaching methods, is 20415.607. This value is spread across 8 degrees of freedom (df), resulting in a Mean Square (the average variability) of 2551.951. The Within Groups Sum of Squares, accounting for variability within each group, is 22403.143 with 71 degrees of freedom, leading to a Mean Square of 315.537.

The F-value, a critical statistic in ANOVA, is calculated at 8.088. This value is derived from the ratio of the Between Groups Mean Square to the Within Groups Mean Square. It serves as a measure of the variance between the group means relative to the variance within the groups. The corresponding significance (Sig.) value of 0.000, substantially below the standard threshold of 0.05, indicates a high level of statistical significance.

This exceptionally low Sig. value strongly suggests that the differences in final exam scores between the groups are statistically significant and not due to random chance. Such a finding underscores the impact of the teaching methodologies employed on student performance. Specifically, it indicates that the method used in the EG (game-based learning) had a significant effect on the students' final exam scores compared to the traditional methods used in the CG, thus validating the effectiveness of the instructional approach used in the experimental setup.

Table 3. One-Way ANOVA results between final exam results and student motivation rates

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	20415.607	8	2551.951	8.088	0.000
Within Groups	22403.143	71	315.537		
Total	42818.750	79			

In Table 4, The Pearson Correlation analysis conducted between final exam results and motivation rates of students within this study presents a profound and statistically significant relationship, pertinent to the field of educational research. The correlation coefficient of 0.815 indicates a strong positive correlation between these two variables. This substantial relationship implies that as students' motivation rates increase, there is a correspondingly significant improvement in their final exam results.

Table 4. Pearson correlation analysis between final exam results and student motivation rates

		Final Exam Results	**Students' Motivation Rate**
Final Exam Results	Pearson Correlation	1	0.815
	Sig. (2-tailed)		0.000
	Sum of Squares and Cross-products	31198.750	2568.625
	N	80	80
Students' Motivation Rate	Pearson Correlation	0.815	1
	Sig. (2-tailed)	0.000	
	Sum of Squares and Cross-products	2568.625	31198.750
	N	80	80

The significance value (Sig.) associated with this correlation is .000 (2-tailed), emphatically suggesting that the correlation is not a product of random chance but a reliable and significant finding. This level of significance is crucial, especially considering the sample size of 80 students, as it validates the consistency and reliability of the observed correlation across the study's population.

This strong positive correlation corroborates existing educational theories that advocate for the intrinsic link between student motivation and academic performance. Particularly in the context of Game-Based Learning (GBL), which was a focus of this study, these findings are insightful. They suggest that the engaging and interactive aspects of GBL significantly contribute to enhancing students' motivation, which in turn positively affects their academic achievements, especially in the context of learning computer science terms.

The additional statistical figures, such as Sum of Squares and Cross-products and Covariance, further reinforce the strength and reliability of this relationship. These metrics provide a comprehensive view of the relationship's dynamics, underpinning the robustness of the correlation.

In conclusion, the study's findings accentuate the critical role of student motivation in educational success and highlight the potential of GBL as an effective tool to boost motivation and, consequently, academic performance in primary school computer science education. This correlation is instrumental for educators and curriculum developers, underscoring the importance of incorporating motivational strategies in educational methodologies to enhance learning outcomes.

Fig. 4 depicts a compelling narrative regarding the efficacy of Game-Based Learning (GBL) compared to traditional learning methods over a period of several weeks. Initially, students in the Experimental Group, who were engaged in GBL, scored lower than their counterparts in the Control Group, who were learning through traditional methods. This initial phase, marked by lower scores in the Experimental Group, can be attributed to the adaptation period required for students to acclimate to the novel GBL approach. Unlike traditional methods, which they were accustomed to, GBL presented a new learning paradigm, necessitating an adjustment period.

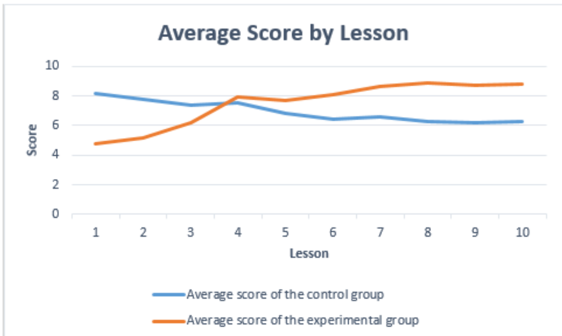

Fig. 4. Average score of experimental group and control group for 10 lessons.

After the first three weeks, a pivotal shift occurred. The scores of the Experimental Group students began to increase, while those of the Control Group students started to decline. This trend is indicative of two crucial factors. Firstly, the increase in scores for the Experimental Group reflects their growing familiarity and comfort with the GBL method. As they became more adept at engaging with the game-based learning format, their academic performance improved. Secondly, the decline in scores for the Control Group suggests a decrease in motivation. The monotony or lack of engagement inherent in traditional learning methods might have contributed to this reduction in enthusiasm and, consequently, lower scores.

The tables and figures referenced (Table 3, Table 4, and Fig. 4) likely provide quantitative backing for these observations, highlighting the correlation between learning methods, motivation levels, and academic performance.

Furthermore, the final scores—9.13 for the Experimental Group versus 5.9 for the Control Group—are a testament to the effectiveness of the GBL approach. This significant difference in performance can be partially attributed to the heightened motivation levels in the Experimental Group, spurred by the engaging nature of the game-based learning method. Additionally, the design of the game, particularly the final tour that required correct identification of internal components of a system block, reinforced learning through repetition and active engagement. The need for students to replay the final tour in the event of a mistake likely cemented their understanding of the subject matter, as reflected in their higher scores in the final task.

In conclusion, the graph and accompanying data suggest that while GBL may require an initial period of adjustment, its long-term benefits in terms of student motivation and learning outcomes are substantial, particularly in comparison to traditional learning methods.

V. Discussion

A. Interpretation of Findings

The interpretation of findings from this study offers crucial insights into the efficacy of Game-Based Learning (GBL) in enhancing the memorization of computer science terminology and motivation among primary school students. These findings are examined in light of the formulated research hypotheses and compared with existing literature in the field.

Firstly, concerning Hypothesis I, which posited that GBL would enhance memorization of computer science terms, the results showed a significant improvement in final exam scores for students in the Experimental Group (EG) who were taught using GBL methods compared to the Control Group (CG) who received traditional instruction. This outcome not only confirms Hypothesis I but also resonates with prior research indicating that interactive and engaging learning methods, like GBL, can lead to better retention of academic content [46, 47]. The incorporation of gaming elements in learning seemingly catalyzes cognitive processes essential for memory retention, aligning with the cognitive theory of multimedia learning [48].

Regarding Hypothesis II, which suggested that GBL would bolster student motivation for computer science studies, the data revealed higher motivation rates in the EG compared to the CG. Although the significance level narrowly missed the conventional threshold, the trend in the data strongly supports the hypothesis. This finding is in congruence with studies by Chen, 2023 [49], which highlighted the motivational benefits of game-like elements in education, emphasizing the role of GBL in fostering intrinsic motivation and engagement.

Contrasting these findings with existing literature, it is evident that the results of this study add to the growing body of evidence supporting the effectiveness of GBL in educational settings. While previous studies have predominantly focused on secondary and higher education levels [50–52], this research extends the application of GBL to primary education, specifically in the context of computer science learning. This extension is significant, considering the early developmental stages of the target demographic and the subject’s traditionally perceived complexity.

In summary, the findings of this study not only reinforce existing literature on the benefits of GBL but also expand its applicability to younger learners in the domain of computer science. This contributes to a more nuanced understanding of how GBL can be utilized effectively in diverse educational contexts and for various learning objectives.

B. Impact of Game Based Learning on Memorization and Motivation

The exploration into the effects of Game-Based Learning (GBL) on the memorization of computer science terms and student motivation yields significant insights, particularly when juxtaposed with traditional teaching methods. The research indicates that GBL has a profound influence on both the cognitive and affective domains of learning among primary school students.

To elucidate how procedural methods and activities in GBL can elevate student learning motivation, it’s pertinent to delve into the intrinsic qualities of these techniques [53, 54]. The engagement fostered by GBL, which merges learning objectives with interactive game elements, inherently motivates students by incorporating elements of challenge, curiosity, and control. These game-based elements stimulate intrinsic motivation through the provision of immediate feedback, achievable goals, and a sense of progression and achievement. Furthermore, aligning with Self-Determination Theory, GBL environments empower students with autonomy, competence, and relatedness, key factors in enhancing intrinsic motivation. By actively involving students in their learning process through interactive and immersive activities, GBL not only diminishes the extraneous cognitive load but also significantly bolsters students’ motivation by making learning a more engaging and meaningful experience.

Moreover, the impact of GBL on student motivation was markedly positive. The Experimental Group displayed increased enthusiasm and engagement in learning, a finding that aligns with the Self-Determination Theory [55], which emphasizes the role of autonomy, competence, and relatedness in fostering intrinsic motivation. GBL, by providing an interactive and autonomous learning environment, fulfills these psychological needs, thereby enhancing motivation. Conversely, the traditional methods, often perceived as monotonous and teacher-centric, failed to sustain student motivation over time.

Furthermore, the design of the game in the Experimental Group, particularly the final task that required the correct identification of system unit components, reinforced learning through repetition and active engagement, a strategy known to enhance memory retention [56]. This aspect of GBL, combined with the inherent motivational elements, contributed to the superior performance of these students compared to their peers in the Control Group.

In summary, the study provides compelling evidence that GBL has a significant positive impact on both the memorization of academic content and the motivation levels of students. These findings highlight the potential of GBL as a more effective and engaging alternative to traditional teaching methods in primary school computer science education.

C. Practical Implications for Educators

The findings from this study on game-based learning (GBL) offer invaluable insights for educators and curriculum designers, especially in the realm of primary school computer science education. The demonstrated efficacy of GBL in enhancing memorization and motivation presents a compelling case for its integration into educational practices.

Firstly, educators should consider incorporating GBL strategies as a supplement to traditional teaching methods. The engaging nature of GBL can serve as a catalyst for learning, particularly in subjects perceived as challenging, like computer science. For effective integration, educators need to align game content with educational objectives, ensuring that the gaming elements are not just entertaining but also educational.

Curriculum designers should look into developing or adopting educational games that are specifically tailored to the curriculum's learning outcomes. These games should be interactive, age-appropriate, and designed to progressively challenge students, thus catering to varying levels of ability and understanding within a primary school setting.

Additionally, it is important to provide professional development opportunities for teachers. Educators need to be equipped with the necessary skills and knowledge to effectively implement GBL in their classrooms. This includes training on selecting appropriate games, integrating them into lesson plans, and using them to complement traditional teaching methods.

Furthermore, educators should employ methods to assess the impact of GBL on student learning. This could involve regular feedback sessions, quizzes, or other assessment tools that help in evaluating the effectiveness of the games in achieving learning objectives.

Incorporating GBL also requires attention to the digital divide. Educators should ensure that all students have equal access to the technology needed for GBL. This might mean investing in school-based resources or finding ways to make these resources available to students who may not have access at home.

In conclusion, the integration of GBL into primary school computer science education offers a promising avenue for enhancing student engagement and learning outcomes. By carefully selecting and implementing game-based tools, educators and curriculum designers can create a more dynamic and effective learning environment that not only educates but also inspires young learners.

VI. Conclusion

This research paper presents a comprehensive examination of the efficacy of Game-Based Learning (GBL) in enhancing the memorization of computer science terms and increasing motivation among primary school students. The study's findings indicate a significant positive impact of GBL on student learning outcomes, as evidenced by higher scores in final exams and increased motivation levels in the Experimental Group exposed to GBL, compared to the Control Group that followed traditional teaching methods. These results are particularly noteworthy in the context of primary education, where engaging and effective learning strategies are crucial for foundational knowledge acquisition. The study extends the understanding of GBL's applicability and effectiveness, moving beyond its traditional use in secondary or higher education and highlighting its potential in younger age groups and challenging subjects like computer science. The research underscores the importance of innovative teaching approaches in the evolving educational landscape, offering insights into how GBL can be effectively integrated into primary education to enhance learning experiences and outcomes.

Moreover, the broader implications of this study for the field of educational technology are profound. It demonstrates the transformative potential of GBL in reshaping educational methodologies, fostering a more interactive and student-centered learning environment. This shift is especially pertinent in the digital era, where technology plays an increasingly significant role in education. The research contributes to the growing body of literature advocating for the integration of technology in education, not merely as a tool for information dissemination but as a catalyst for engagement, understanding, and motivation. Moving forward, the findings from this study can inform future research directions, exploring the application of GBL across various educational settings and subjects, and paving the way for a more nuanced and effective use of technology in education.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

AA developed the research question, designed the methodology, and led the writing and revision of the manuscript. AA and AT developed the educational gaming software, assisted with its classroom implementation, and provided feedback on the manuscript. LA and VS interacted with participating schools. AA and VS conducted statistical analysis and contributed to the methodology and results sections of the paper. RM conducted the literature review, contributed to the discussion section, and interpreted the findings in a broader context. All authors had approved the final version.

References

[1] N. Bado, “Game-based learning pedagogy: a review of the literature,” *Interactive Learning Environments*, pp. 1–13, Oct. 2019. doi: https://doi.org/10.1080/10494820.2019.1683587

[2] L.-H. Wang, B. Chen, G.-J. Hwang, J.-Q. Guan, and Y.-Q. Wang, “Effects of digital game-based STEM education on students’ learning achievement: A meta-analysis,” *International Journal of STEM Education*, vol. 9, no. 1, Mar. 2022. doi: https://doi.org/10.1186/s40594-022-00344-0

[3] M. H. Hussein, S. H. Ow, M. M. Elaish, and E. O. Jensen, “Digital game-based learning in K-12 mathematics education: A systematic literature review,” *Education and Information Technologies*, Sep. 2021. doi: https://doi.org/10.1007/s10639-021-10721-x

[4] W. Mao, Y. Cui, M. M. Chiu, and H. Lei, “Effects of game-based learning on students’ critical thinking: A meta-analysis,” *Journal of Educational Computing Research*, vol. 59, no. 8, p. 073563312110070, Apr. 2021. doi: https://doi.org/10.1177/07356331211007098

[5] Ni, K. Rijal, and N. W. B. Grendis, “Examining STEM students’ computational thinking skills through interactive practicum utilizing technology,” *International Journal of Essential Competencies in Education*, vol. 2, no. 1, pp. 54–65, Jun. 2023. doi: https://doi.org/10.36312/ijece.v2i1.1360

[6] Z. Cai, P. Mao, D. Wang, J. He, X. Chen, and X. Fan, “Effects of scaffolding in digital game-based learning on student’s achievement: A three-level meta-analysis,” *Educational Psychology Review*, Jan. 2022. doi: https://doi.org/10.1007/s10648-021-09655-0

[7] L. Petrović, D. Stojanović, S. Mitrović, D. Barać, and Z. Bogdanović, “Designing an extended smart classroom: An approach to game-based learning for IoT,” *Computer Applications in Engineering Education*, Jul. 2021. doi: https://doi.org/10.1002/cae.22446

[8] B. Kaldarova *et al*., “Applying game-based learning to a primary school class in computer science terminology learning,” *Frontiers in Education*, vol. 8, Feb. 2023. doi: https://doi.org/10.3389/feduc.2023.1100275

[9] L. Sun, Z. Guo, and D. Zhou, “Developing K-12 students’ programming ability: A systematic literature review,” *Education and Information Technologies*, Feb. 2022. doi: https://doi.org/10.1007/s10639-022-10891-2

[10] N. Omarov *et al*., “Applying artificial intelligence and computer vision for augmented reality game development in sports,” *International Journal of Advanced Computer Science and Applications*, vol. 14, no. 8, Jan. 2023. doi: https://doi.org/10.14569/ijacsa.2023.0140876

[11] A. Rasti-Behbahani and M. Shahbazi, “Investigating the effectiveness of a digital game-based task on the acquisition of word knowledge,” *Computer Assisted Language Learning*, vol. 35, no. 8, pp. 1–25, Dec. 2020. doi: https://doi.org/10.1080/09588221.2020.1846567

[12] B. Doskarayev *et al*., “Development of computer vision-enabled augmented reality games to increase motivation for sports,” *International Journal of Advanced Computer Science and Applications (IJACSA)*, vol. 14, no. 4, 2023. doi: https://doi.org/10.14569/IJACSA.2023.0140428

[13] M. Rüth, A. Birke, and K. Kaspar, “Teaching with digital games: How intentions to adopt digital game-based learning are related to personal characteristics of pre-service teachers,” *British Journal of Educational Technology*, Feb. 2022. doi: https://doi.org/10.1111/bjet.13201

[14] Z. Bahroun, C. Anane, V. Ahmed, and A. Zacca, “Transforming education: A comprehensive review of generative artificial intelligence in educational settings through bibliometric and content analysis,” *Sustainability*, vol. 15, no. 17, p. 12983, Jan. 2023. doi: https://doi.org/10.3390/su151712983

[15] A. Shi, Y. Wang, and N. Ding, “The effect of game–based immersive virtual reality learning environment on learning outcomes: Designing an intrinsic integrated educational game for pre–class learning,” *Interactive Learning Environments*, pp. 1–14, Oct. 2019. doi: https://doi.org/10.1080/10494820.2019.1681467

[16] Y. Pan, F. Ke, and X. Xu, “A systematic review of the role of learning games in fostering mathematics education in K-12 settings,” *Educational Research Review*, vol. 36, p. 100448, Jun. 2022. doi: https://doi.org/10.1016/j.edurev.2022.100448

[17] R. M. Martins and C. G. Wangenheim, “Findings on teaching machine learning in high school: A ten-year systematic literature review,” *Informatics in Education*, Sep. 2022. doi: https://doi.org/10.15388/infedu.2023.18

[18] C.-T. Li, H.-T. Hou, M.-C. Li, and C.-C. Kuo, “Comparison of mini-game-based flipped classroom and video-based flipped classroom: An analysis of learning performance, flow and concentration on discussion,” *The Asia-Pacific Education Researcher*, Apr. 2021. doi: https://doi.org/10.1007/s40299-021-00573-x

[19] Y.-P. Cheng, C.-F. Lai, Y.-T. Chen, W.-S. Wang, Y.-M. Huang, and T.-T. Wu, “Enhancing student’s computational thinking skills with student-generated questions strategy in a game-based learning platform,” *Computers & Education*, vol. 200, p. 104794, Jul. 2023. doi: https://doi.org/10.1016/j.compedu.2023.104794

[20] Y.-P. Cheng, C.-F. Lai, Y.-T. Chen, W.-S. Wang, Y.-M. Huang, and T.-T. Wu, “Enhancing student’s computational thinking skills with student-generated questions strategy in a game-based learning platform,” *Computers & Education*, vol. 200, p. 104794, Jul. 2023. doi: https://doi.org/10.1016/j.compedu.2023.104794

[21] X. Qiu, C.-K. Chiu, L.-L. Zhao, C.-F. Sun, and S. Chen, “Trends in VR/AR technology-supporting language learning from 2008 to 2019: A research perspective,” *Interactive Learning Environments*, pp. 1–24, Jan. 2021. doi: https://doi.org/10.1080/10494820.2021.1874999

[22] H. Antonopoulou, C. Halkiopoulos, E. Gkintoni, and A. Katsimpelis, “Application of gamification tools for identification of neurocognitive and social function in distance learning education,” *International Journal of Learning, Teaching and Educational Research*, vol. 21, no. 5, pp. 367–400, May 2022. doi: https://doi.org/10.26803/ijlter.21.5.19

[23] X. Xia and W. Qi, “Early warning mechanism of interactive learning process based on temporal memory enhancement model,” *Education and Information Technologies*, Jul. 2022. doi: https://doi.org/10.1007/s10639-022-11206-1

[24] M. (Sebrina) Wang, L.-Z. Yang, and T. (Charline) Chen, “The effectiveness of ICT-enhanced learning on raising intercultural competencies and class interaction in a hospitality course,” *Interactive Learning Environments*, pp. 1–13, Sep. 2020. doi: https://doi.org/10.1080/10494820.2020.1815223

[25] M. Bourbour, “Using digital technology in early education teaching: learning from teachers’ teaching practice with interactive whiteboard,” *International Journal of Early Years Education*, vol. 31, no. 1, pp. 1–18, Nov. 2020. doi: https://doi.org/10.1080/09669760.2020.1848523

[26] D. Bulut, Y. Samur, and Z. Cömert, “The effect of educational game design process on students’ creativity,” *Smart Learning Environments*, vol. 9, no. 1, p. 8, 2022. https://doi.org/10.1186/s40561-022-00188-9

[27] A. N. Saleem, N. M. Noori, and F. Ozdamli, “Gamification applications in e-learning: A literature review,” *Technology, Knowledge and Learning*, vol. 27, no. 1, pp. 139–159, Jan. 2021. doi: https://doi.org/10.1007/s10758-020-09487-x

[28] L. Zheng, M. Long, L. Zhong, and J. F. Gyasi, “The effectiveness of technology-facilitated personalized learning on learning achievements and learning perceptions: A meta-analysis,” *Education and Information Technologies*, May 2022. doi: https://doi.org/10.1007/s10639-022-11092-7

[29] G. K. Kumar *et al*., “Internet of things sensors and support vector machine integrated intelligent irrigation system for agriculture industry,” *Discover Sustainability*, vol. 5, no. 1, Jan. 2024. doi: https://doi.org/10.1007/s43621-024-00179-5

[30] K.-P. Thai, H. J. Bang, and L. Li, “Accelerating early math learning with research-based personalized learning games: A cluster randomized controlled trial,” *Journal of Research on Educational Effectiveness*, vol. 15, no. 1, pp. 1–24, Sep. 2021. doi: https://doi.org/10.1080/19345747.2021.1969710

[31] F. Dahalan, N. Alias, and M. S. N. Shaharom, “Gamification and game based learning for vocational education and training: A systematic literature review,” *Education and Information Technologies*, Jan. 2023. doi: https://doi.org/10.1007/s10639-022-11548-w

[32] K. D. Stiller and S. Schworm, “Game-based learning of the structure and functioning of body cells in a foreign language: Effects on motivation, cognitive load, and performance,” *Frontiers in Education*, vol. 4, Mar. 2019. doi: https://doi.org/10.3389/feduc.2019.00018

[33] X.-M. Wang, S.-M. Wang, J.-N. Wang, G.-J. Hwang, and S. Xu, “Effects of a two-tier test strategy on students’ digital game-based learning performances and flow experience in environmental education,” *Journal of Educational Computing Research*, vol. 60, no. 8, pp. 1942–1968, Apr. 2022. doi: https://doi.org/10.1177/07356331221095162

[34] F. Djelil and E. Sanchez, “Game design and didactic transposition of knowledge. The case of progo, a game dedicated to learning object-oriented programming,” *Education and Information Technologies*, Jun. 2022. doi: https://doi.org/10.1007/s10639-022-11158-6

[35] C. Y. Chang and G. J. Hwang, "Trends in digital game-based learning in the mobile era: A systematic review of journal publications from 2007 to 2016," *International Journal of Mobile Learning and Organisation*, vol. 13, no. 1, p. 68, 2019. doi: https://doi.org/10.1504/ijmlo.2019.096468
[36] Z. Lu, M. M. Chiu, Y. Cui, W. Mao, and H. Lei, "Effects of Game-Based Learning on Students' Computational Thinking: A meta-analysis," *Journal of Educational Computing Research*, p. 073563312211007, Jun. 2022. doi: https://doi.org/10.1177/07356331221100740
[37] C.-C. Chang and S.-T. Yang, "Interactive effects of scaffolding digital game-based learning and cognitive style on adult learners' emotion, cognitive load and learning performance," *International Journal of Educational Technology in Higher Education*, vol. 20, no. 1, Mar. 2023. doi: https://doi.org/10.1186/s41239-023-00385-7.
[38] T. Partovi and M. R. Razavi, "The effect of game-based learning on academic achievement motivation of elementary school students," *Learning and Motivation*, vol. 68, no. 1, p. 101592, Nov. 2019. doi: https://doi.org/10.1016/j.lmot.2019.101592
[39] C. C. Ekin, E. Polat, and S. Hopcan, "Drawing the big picture of games in education: A topic modeling-based review of past 55 years," *Computers & Education*, vol. 194, p. 104700, Mar. 2023. doi: https://doi.org/10.1016/j.compedu.2022.104700
[40] C. Udeozor, R. Toyoda, F. Russo Abegão, and J. Glassey, "Digital games in engineering education: systematic review and future trends," *European Journal of Engineering Education*, pp. 1–19, Jun. 2022. doi: https://doi.org/10.1080/03043797.2022.2093168
[41] C. Udeozor, R. Toyoda, F. R. Abegão, and J. Glassey, "Perceptions of the use of virtual reality games for chemical engineering education and professional training," *Higher Education Pedagogies*, vol. 6, no. 1, pp. 175–194, Jan. 2021. doi: https://doi.org/10.1080/23752696.2021.1951615
[42] I. Wati, "Introducing a structured problem-solving approach through lesson study: A case study of one fijian teacher's professional learning," *ERIC*, 2023.
[43] T. Lee *et al*., "Investigation of virtual & augmented reality classroom learning environments in university STEM education," *Interactive Learning Environments*, pp. 1–16, Dec. 2022. doi: https://doi.org/10.1080/10494820.2022.2155838
[44] S. Avinash, P. Deshmukh, P. Jamsandekar, R. D. Kumbhar, J. Kharade, and R. Rajendran, "Specifying the virtual reality approach in mobile gaming using unity game engine," *Lecture Notes in Networks and Systems*, pp. 289–300, Jan. 2023. doi: https://doi.org/10.1007/978-981-99-1946-8_26
[45] K. Simion, "Qualitative and quantitative approaches to rule of law research," *SSRN Electronic Journal*, 2016. doi: https://doi.org/10.2139/ssrn.2817565
[46] X. Li, Y. Tian, and L. Xu, "PiEvE: A dual-mode game-based plug-in approach applying bullet screen in virtual classrooms," Mar. 2023. doi: https://doi.org/10.1109/icaie56796.2023.00027
[47] Y. Zhang, A. Nowak, A. Romanowski, and M. Fjeld, "Virtuality or physicality? Supporting memorization through augmented reality gamification," Jun. 2023. doi: https://doi.org/10.1145/3596454.3597183
[48] B. Omarov, S. Narynov, Z. Zhumanov, A. Gumar, and M. Khassanova, "A skeleton-based approach for campus violence detection," *Computers, Materials & Continua*, 2022, vol. 72, no. 1. http://dx.doi.org/10.32604/cmc.2022.024566
[49] Y. Chen, "Integrating a game-based app to enhance translation learners' engagement, motivation, and performance," *International Journal of Instruction*, vol. 16, no. 2, pp. 759–782, Apr. 2023. doi: https://doi.org/10.29333/iji.2023.16240a
[50] N. Almusharraf, M. Aljasser, H. Dalbani, and D. Alsheikh, "Gender differences in utilizing a game-based approach within the EFL online classrooms," *Heliyon*, 2023, vol. 9, no. 2. https://doi.org/10.1016/j.heliyon.2023.e13136
[51] M. Leitner, E. Greenwald, N. Wang, R. Montgomery, and C. Merchant, "Designing game-based learning for high school artificial intelligence education," *International Journal of Artificial Intelligence in Education*, Apr. 2023. doi: https://doi.org/10.1007/s40593-022-00327-w
[52] Y.-P. Cheng, C.-F. Lai, Y.-T. Chen, W.-S. Wang, Y.-M. Huang, and T.-T. Wu, "Enhancing student's computational thinking skills with student-generated questions strategy in a game-based learning platform," *Computers & Education*, vol. 200, p. 104794, Jul. 2023. doi: https://doi.org/10.1016/j.compedu.2023.104794
[53] C.-C. Chang and S.-T. Yang, "Interactive effects of scaffolding digital game-based learning and cognitive style on adult learners' emotion, cognitive load and learning performance," *International Journal of Educational Technology in Higher Education*, vol. 20, no. 1, Mar. 2023. doi: https://doi.org/10.1186/s41239-023-00385-7.
[54] Y. K. Erdoğmuş and A. A. Kurt, "Digital game-based learning: Pedagogical agent and feedback types on achievement, flow experience, and cognitive load," *Education and Information Technologies*, Dec. 2023. doi: https://doi.org/10.1007/s10639-023-12368-2
[55] M. A. Maillet and F. M. E. Grouzet, "Understanding changes in eating behavior during the transition to university from a self-determination theory perspective: a systematic review," *Journal of American College Health*, vol. 71, no. 2, pp. 1–18, Jul. 2021. doi: https://doi.org/10.1080/07448481.2021.1891922
[56] J. Ivan *et al*., "Fostering pre-service physical educators' retention of concepts in a professional education course using moneypoly game," *International Journal of Multidisciplinary*, vol. 4, no. 9, pp. 3366–3389, Sep. 2023. doi: https://doi.org/10.11594/ijmaber.04.09.24