

PAPER

Enhancing Early Childhood Cognitive Development via Mobile Game-Based Learning Applications: Insights and Practical Experiences

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ABSTRACT

Early childhood cognitive development is foundational for future academic and personal success. While traditional teaching approaches often overlook technology's potential, game-based learning applications offer an innovative solution to enhance cognitive abilities in young children. This study evaluates the feasibility and effectiveness of a game-based learning (GBL) application for enhancing early childhood cognitive abilities. Using Research and Development (R&D) methodology, 40 children aged 5–6 were randomly assigned to experimental and control groups for an eight-week intervention. The application was developed through systematic needs analysis, design, development, implementation, and evaluation. ANCOVA analysis of pre- and post-test assessments demonstrated highly significant effects ($F = 2154.89$, $p < 0.001$, partial $\eta^2 = 0.966$), explaining 96.6% of score variations. Expert validation scores exceeded 4.6 out of 5.0, confirming the application's quality. Qualitative feedback from teachers and parents noted substantial improvements in children's problem-solving skills, memory retention, and critical thinking. These findings suggest that integrating GBL applications could enhance educational equity and improve cognitive development outcomes across diverse educational settings.

KEYWORDS

mobile learning, game-based learning (GBL), cognitive development, early childhood education (ECE)

1 INTRODUCTION

The cognitive development of young children is essential for establishing the groundwork for learning and thought processes, playing a vital role in overall childhood growth and brain development [1]. Early cognitive development significantly influences later life outcomes, including academic achievement and

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educational attainment [2]. However, current approaches in early childhood education (ECE) often need to provide comprehensive cognitive stimulation.

Recent studies have highlighted critical challenges in ECE learning processes. Observations across multiple institutions reveal that traditional teaching methods predominantly focus on basic motor skills and academic activities, often overlooking crucial aspects of cognitive development. A survey of 50 ECE institutions found that 80% of educators prioritize basic literacy and numeracy skills, while critical thinking, problem-solving, and creativity receive less attention (author's survey data, 2023). This imbalance in educational approaches has raised concerns about children's overall cognitive development.

Game-based learning (GBL) has emerged as a potential solution, though its implementation has opportunities and challenges. While digital GBL shows promise in enhancing children's learning experiences and integrating educational content with entertainment [3], [4], successful implementation requires careful consideration of factors such as age-appropriate content design [5], screen time management [6], [7], and educator preparation [8], [9]. When properly implemented, digital game-based learning has demonstrated significant potential in enhancing children's learning experiences and cognitive development [10], [11].

Studies have demonstrated that well-designed digital learning environments can positively impact creative thinking and critical thinking skills [12], [13], [14]. The integration of touchscreen technology has further facilitated multimodal learning experiences in early education settings [15]. However, the rapidly evolving nature of technology presents ongoing challenges for implementation and assessment [11], [16], highlighting the need for adaptive and sustainable approaches to incorporating GBL into ECE [17], [18].

In light of this, creating cognitive stimulation game applications for young children is essential for harmonizing academic education with play-based skills. These apps offer stimulating cognitive challenges and connect conventional learning methods with the digital era, addressing the decline in creativity and problem-solving abilities. Furthermore, such applications can assist educators in enhancing the quality of instruction and fostering digital competencies. This highlights the necessity for an adaptive and sustainable strategy in incorporating GBL into the ECE curriculum.

Based on these considerations, this study addresses the following research questions:

- RQ1. How can we develop GBL to stimulate early childhood cognition?
- RQ2. What is the feasibility of GBL in stimulating early childhood cognition?
- RQ3. What is the effectiveness of GBL in stimulating early childhood cognition?

2 LITERATURE REVIEW

Over the past ten years, ECE has experienced considerable changes, particularly with integrating digital technology into learning. One method that has gained prominence is GBL, which merges playful activities with educational goals. This literature review will examine how GBL can enhance cognitive development in young children.

2.1 Early childhood cognitive development

Cognitive development during early childhood has been widely recognized as a crucial foundation for future learning and critical thinking abilities [19]. While this

fundamental connection is well-established, a critical examination of existing research reveals significant insights and notable limitations in our current understanding. Recent longitudinal studies have emphasized the pivotal role of the first five years of life in brain development and cognitive growth [20]. These studies have demonstrated the profound impact of environmental stimulation on neural plasticity and cognitive development. However, most research has focused primarily on general environmental factors, leaving gaps in our understanding of specific intervention strategies that most effectively support cognitive development at different developmental stages.

Several influential studies have examined the relationship between early cognitive development and later outcomes. Recent research suggests that cognitive abilities developed in early childhood can predict future academic and behavioral outcomes [21]. While these findings are compelling, they often rely on traditional measures of cognitive ability that may not capture the full spectrum of early childhood cognitive development.

2.2 Game-based learning and cognitive development

Game-based learning is an instructional strategy that integrates educational materials into games to enhance student engagement [22], [23]. While this approach shows promise for ECE, existing literature reveals significant gaps in understanding how to optimally develop and implement GBL specifically for cognitive stimulation in young children.

Regarding game development aspects, a comprehensive meta-analysis by [24] revealed that purpose-built educational games demonstrate greater effectiveness compared to adapted commercial games, particularly in foundational skills such as language and mathematics. However, the study needed to adequately address the specific design principles for early childhood cognitive development. While studies [25], [26], [27] highlight the importance of engagement and motivation in game design, they primarily focus on older children, leaving questions about developmentally appropriate design features for early childhood largely unexplored.

The feasibility of implementing GBL in educational settings has been documented in various contexts [12], [13], yet studies examining implementation specifically in early childhood settings still need to be explored. The integration of touchscreen technology in preschool classrooms [28], [29] suggests potential for successful implementation. Still, research must sufficiently address practical considerations such as teacher training requirements, resource availability, and classroom management strategies for young children using educational games. This gap in understanding implementation feasibility represents a critical area needing further investigation.

Concerning effectiveness, several studies have shown that digital game-based learning (DGBL) can enhance critical thinking and problem-solving abilities in children [30]. DGBL environments also demonstrate potential for strengthening social skills and improving learning motivation [31]. However, these studies often need more rigorous evaluation of cognitive developmental outcomes specific to early childhood. While research indicates that GBL can help overcome learning barriers such as anxiety and low motivation [17], [18], most effective studies focus on academic achievement rather than cognitive development markers appropriate for young children.

The ongoing evolution of gaming technology [11] presents opportunities and challenges for early childhood education. Current research must adequately address how technological advances can be leveraged specifically for cognitive stimulation in young children while maintaining developmental appropriateness. This represents a significant gap in the literature.

2.3 Effectiveness of game-based learning

Game-based learning has demonstrated considerable effectiveness across multiple educational settings, particularly early childhood development. A study by [32] found that this approach significantly benefits children's physical and cognitive growth. By facilitating independent learning, fostering active interaction, and encouraging enthusiastic responses, GBL creates an enjoyable environment that boosts participation, enhances motivation, and improves academic outcomes. Additionally, [33] highlights the crucial role of early childhood as a foundational period for developing essential educational skills. At this stage, play-based approaches develop cognitive abilities and facilitate the acquisition of various skills essential for children's holistic growth, thus preparing them better for later stages of education. Despite the promising potential of play-based learning, [34] cautions that the market for high-quality apps for children still needs to grow. Many existing apps emphasize entertainment rather than cognitive value. This suggests an urgent need to develop GBL apps that focus more on children's cognitive enhancement, combining entertainment aspects with substantial educational value to maximize early childhood development potential.

2.4 Challenges and Considerations in GBL Implementation

Although GBL shows considerable promise, its implementation in ECE faces significant challenges. Previous research identified several barriers, including inadequate technological infrastructure, time constraints, and insufficient teacher preparation [35]. However, their study focused broadly on digital technology adoption without providing specific solutions for GBL implementation. Meanwhile, [36] highlighted concerns about educational apps needing a foundation in learning science principles. They did not offer practical frameworks for selecting and implementing appropriate educational games in early childhood settings.

This study addresses these limitations by developing practical guidelines for effective GBL implementation in ECE, focusing specifically on teacher training protocols and evaluation frameworks for selecting age-appropriate educational games.

3 RESEARCH METHODOLOGY

3.1 Research design

The methodology employed in this study is Research and Development (R&D), which focuses on creating new products while assessing their feasibility and effectiveness. Conducting a needs analysis is crucial before implementing the product to ensure it aligns with user requirements. Additionally, evaluating the product's performance is essential to confirm that it operates effectively and benefits its users. The Lee and Owens model was selected for developing the cognitive stimulation game due to its systematic and comprehensive approach, making it well-suited for creating interactive learning media [37]. This model emphasizes a thorough needs assessment, considers the learning context, and offers flexibility to adapt to specific requirements. Moreover, the Lee and Owens model incorporates instructional design principles, supports ongoing formative evaluations, and places particular importance on the testing and revision phases [38]. The design framework of the Lee and Owens model is illustrated in Figure 1.

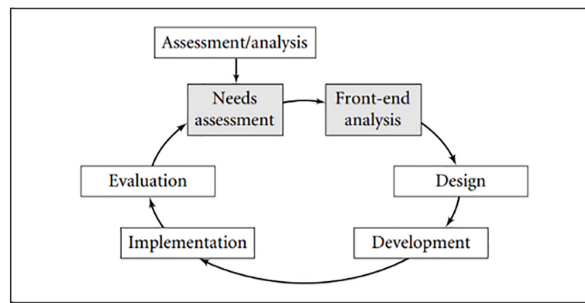


Fig. 1. Lee and Owen development model

Here are the steps of the Lee and Owens development model:

- a) Needs analysis: A needs analysis was conducted to gain an in-depth understanding of early childhood cognitive development. One aspect that continues to develop is memory and attention skills. To train these two abilities, the game aims to stimulate early childhood cognitive abilities in understanding the concepts of difference, classification, patterning, and sorting.
- b) Front-end analysis: The front-end analysis of the developed game involves a deep understanding of the user interface (UI) and user experience (UX) suitable for early childhood. The UI includes a bright visual design, large and clear icons and buttons for children to interact with the game quickly, and clear feedback when children answer questions correctly. UX, such as interactive and child-friendly tutorials, helps children understand the rules and how to play the game appropriately.
- c) Design: The game storyboard is created at this stage by considering the appropriate material to stimulate early childhood cognitive development. The game storyboard includes two main menus: “Inspirational Images” and “Games.”
- d) Development: This process includes 1) the creation of 2D assets in *CorelDRAW*, 2) the creation of applications in *Unity 2020.3*, and 3) the creation of programs in *Visual Studio Code*.
- e) Implementation: During this phase, the developer performs tests to confirm that users can easily access the game. Additionally, these tests evaluate the game’s usability, focusing on user interface interaction, responsiveness, and navigation simplicity to guarantee an optimal gaming experience for players.
- f) Evaluation: The primary emphasis of the evaluation was to determine how effectively the game application could promote cognitive development in early childhood. This assessment aimed to measure learning outcomes and pinpoint areas that require enhancement to improve the quality and efficacy of the game.

3.2 Research sample

This study was conducted at Harapan Bunda Loli Tasiburi Kindergarten, Donggala Regency, Central Sulawesi Province, focusing on group B children aged 5–6 years. The sample size of 40 children was determined based on statistical requirements for parametric tests. Stevens (2020) recommends that 30 participants be selected for ANCOVA. With 20 children per group (control and experimental), the sample size exceeds these minimum requirements. Additionally, [39] suggests that this sample

size provides adequate statistical power ($\beta = 0.80$) at $\alpha = 0.05$ for detecting medium effect sizes in educational research.

Participant selection followed specific inclusion and exclusion criteria. Inclusion criteria were: (1) children aged 5–6 years enrolled in group B, (2) regular attendance record (minimum 85% attendance in the previous semester), (3) basic familiarity with touchscreen devices, and (4) no diagnosed learning disabilities. Exclusion criteria included (1) chronic health conditions that might affect regular participation, (2) planned relocation during the study period, and (3) participation in other educational intervention programs.

The study adhered to strict ethical guidelines following research principles with young children. Before beginning the research, institutional approval was obtained from the University Ethics Committee. Written informed consent was obtained from parents/legal guardians of all participating children, with information provided in both Indonesian. The consent form detailed (1) the study purpose and procedures, (2) potential benefits and risks, (3) confidentiality measures, (4) the voluntary nature of participation, and (5) the right to withdraw at any time without consequences.

The participants were divided into experimental ($n = 20$) and control ($n = 20$). The experimental group engaged in learning activities using digital game-based learning applications for 30 minutes per session, three times a week, focusing on cognitive development. Meanwhile, the control group participated in conventional learning activities for the same duration and frequency, using traditional teaching materials such as worksheets, flashcards, and physical manipulatives to learn similar cognitive concepts. To minimize instructor bias, both groups were taught by teachers with comparable qualifications (minimum S1 degree in ECE) and teaching experience (minimum five years). Regular monitoring ensured consistent implementation across both groups.

3.3 Research instruments

This study used instruments in the form of observation sheets and questionnaires. The National Association for the Education of Young Children (NAEYC) recommends the use of observation as the primary method in early childhood assessment, emphasizing that assessment should be “ongoing, strategic, and purposeful” [40]. The instrument developed consists of 28 items related to early childhood cognitive abilities. The instrument validation process used the expert judgment method, involving three experts (two ECE experts and one research instrument development expert). This instrument validation also uses the content validity index (CVI) method. The validation results showed that this instrument’s scale content validity index (S-CVI) reached 1.00, indicating a very high level of validity, as all experts agreed on each item. In addition, the instrument’s reliability was tested with Cronbach’s alpha, and the average Cronbach’s alpha value of all items was 0.874, so $r_{count} > r_{table}$, it can be concluded that all questionnaire items are valid.

3.4 Data analysis technique

Evaluation of the game application involved assessments from learning media experts and material experts, as well as a survey to assess the feasibility and acceptability of the application. Scores from the experts were given in the range of 1–5, where the highest score indicates the quality of the learning media. Questionnaire data were analyzed using descriptive statistics, including calculation of mean and

standard deviation, with standard deviation more minor than the mean, indicating good data acceptance.

This study utilized a comprehensive set of data analysis techniques to evaluate the effectiveness of using cognitive stimulation games. The analysis began with the Shapiro-Wilk normality test and Levene's homogeneity test to ensure the data conformed to the assumptions of parametric statistics. Next, an independent t-test was used to compare the post-test results between the two groups. For a more in-depth analysis, ANCOVA was applied to evaluate the effect of the intervention while controlling for pre-test differences. ANCOVA was chosen because this method allows the researcher to compare the post-test results between the two groups while controlling for any differences in the pre-test scores. We must ensure that the differences we observe are genuinely due to the GBL intervention, not differences in learners' initial abilities. N-Gain analysis was used to measure the relative improvement in learning, providing an additional perspective on the effectiveness of the intervention.

4 RESEARCH RESULT AND DISCUSSION

4.1 GBL application development

The developed GBA application is called the Cognitive Stimulation Game. This game aims to enhance children's cognitive skills through engaging and educational activities, leveraging technological advancements. According to [41], applications accessible via tablets and smartphones facilitate flexible learning unrestricted by time or location. Among various digital technologies, touchscreen mobile devices are the most preferred choice for children, and their popularity continues to increase [42]. Therefore, cognitive stimulation games are developed as mobile applications that are very well designed, considering the needs and development of early childhood. This is based on the findings of a meta-analysis [34] that well-designed applications can increase children's engagement and encourage them to invest more deeply in the learning process.

Figure 2 illustrates the main menu of the Cognitive Stimulation Game, showcasing a user-friendly interface designed for easy navigation by children.



Fig. 2. Main menu of cognitive stimulation game

Main menu: There are two options on the main menu: "Inspirational Images" and "Games." The "inspirational images" option contains illustrations or images that can provide inspiration or ideas to spark early knowledge. The "games" option contains materials related to difference, classifying, patterning, and sorting concepts. This material has been adapted to the ECE curriculum.



Fig. 3. Theme selection

Choice of theme: In Figure 3, children can choose a theme according to their interests. The themes provided are animals, transportation, and plants. Each theme is designed to provide an interactive and educational play experience, focusing on concept recognition and stimulating children’s cognitive abilities through exciting visuals.



Fig. 4. Animals theme

Animals theme: As shown in Figure 4, the animals theme allows children to choose land, aquatic, or air animals according to their interests.

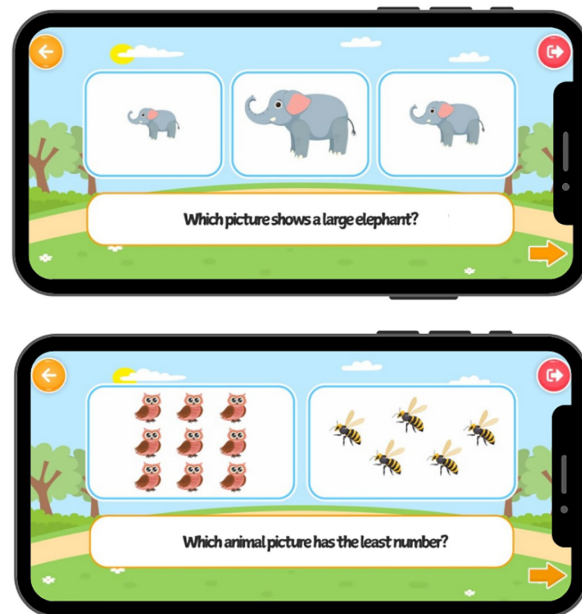


Fig. 5. Conceptualizing differences based on size and number of images

The concept of difference: At the start of the game, illustrated in Figure 5, children are engaged in an interactive task that encourages them to grasp the idea of differences in size and quantity. Following the audio prompts, they are instructed to identify and choose the most significant animal and the one representing the smallest quantity. This method aligns with the research by [43], which indicates that educational games can enhance motivation for learning, prompting children to continue practicing and refining their abilities. Additionally, the game’s design goes beyond merely teaching fundamental mathematical concepts, such as size and quantity; it also promotes social and emotional growth in children. This aligns with [44], highlighting the significance of a comprehensive approach in educational game development.

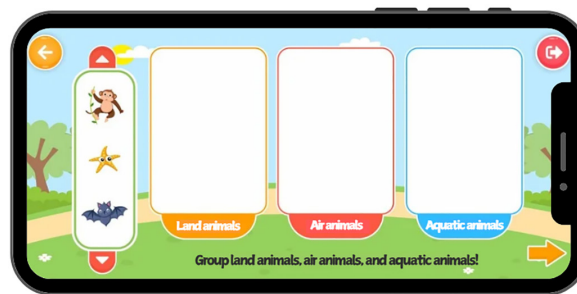


Fig. 6. The concept of classifying

The concept of classifying: Figure 6 shows how a cognitive stimulation game develops the classification concept, inviting children to categorize animals based on land, air and aquatic habitats. This activity improves classification skills and stimulates children’s curiosity to solve problems through visual appeal. According to [45], this approach can increase children’s satisfaction and engagement in learning. According to [46], focusing on elements such as curiosity, fantasy, and challenge in digital game design can enhance children’s interest and motivation and strengthen their interaction with the game. In line with these findings, [47] found that using digital games with various interactive attributes effectively increased learning motivation and created a better learning experience in a DGBL environment.

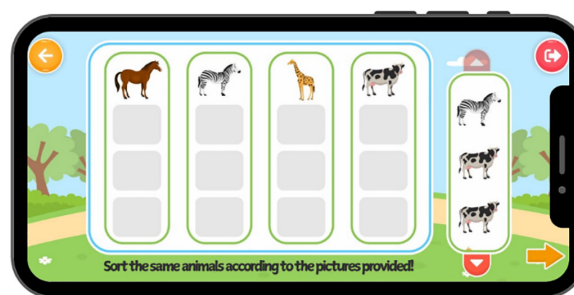


Fig. 7. Arranging the pattern

Composing patterns: In Figure 7, children are stimulated to make patterns based on sample pictures. The child is asked to move the animal image from the right side to the corresponding column to make a pattern or match the same image. This activity reflects some of the advantages of digital games in learning. First, as suggested by [48], the game allows children to repeat the task repeatedly, even when making mistakes, providing an opportunity to learn from trial and improve their understanding of patterns. Secondly, in line with the findings of [49], this activity

provides opportunities for children to actively participate and explore in the learning process, stimulating their cognitive engagement. In addition, the game's interactive nature can increase children's confidence in learning, as they can immediately see the results of their actions and get immediate feedback [50].

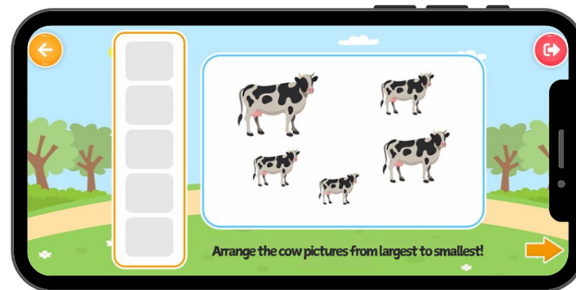


Fig. 8. The concept of sorting

The concept of sorting: Figure 8 shows the concept of sorting. In this section, children are stimulated to sort the giant picture to the smallest or vice versa. This activity utilizes several advantages of digital games in learning. First, games provide the benefit of immediate feedback [51]. This lets children know immediately whether the sequence they made is correct or needs to be corrected. This aligns with the findings of [52], who stated that using digital games in learning can create a context that facilitates increased student interest in learning. The immediate feedback and interactivity of the game make the sort learning process more exciting and engaging.

4.2 Feasibility of game-based learning

Game-based learning was validated by three learning media experts and three material experts. It aims to assess the application's various technical and functional aspects, including learning media feasibility, interface design, media quality and usability, technical aspects such as connectivity and download speed, material clarity, influence/impact on learners, and learning feasibility.

The learning media expert validation used 25 statement items grouped into four main aspects. Each item is rated using a 5-point Likert scale, where point 1 indicates "strongly disagree" and point 5 indicates "strongly agree."

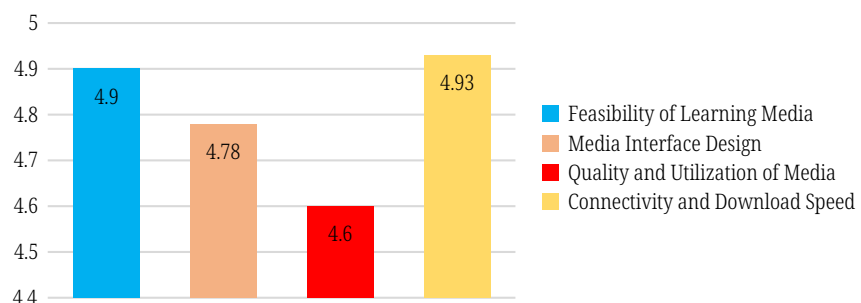


Fig. 9. Learning media expert validation results

Based on the graph in Figure 9, the aspect of connectivity and download speed obtained the highest score (4.93), the aspect of learning media feasibility (4.9), media interface design 4.78, and quality and use of media (4.6). The developed game-based learning is valid and feasible to implement in early childhood.

The following validation was conducted by material experts with expertise in early childhood education and curriculum development. The assessment included 23 items grouped into three main aspects: clarity of learning, influence/impact on learners, and feasibility of learning.

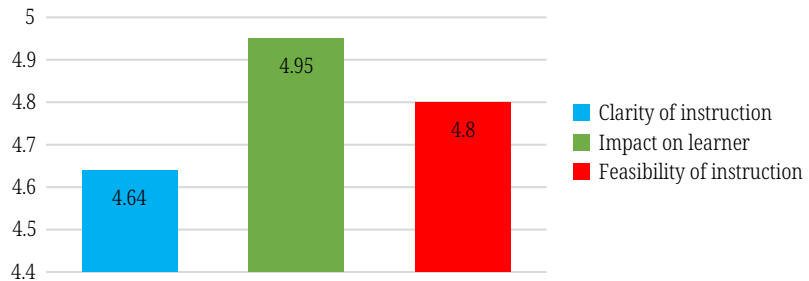


Fig. 10. Material expert validation results

The diagram analysis in Figure 10 shows very positive results for all aspects evaluated. The aspect of influence or impact on learners obtained the highest score (4.95), followed by the aspect of learning feasibility (4.8) and the aspect of learning clarity, with a score of 4.64. Based on these results, the game-based learning developed is feasible and influenced by early childhood characteristics.

However, it is essential to remember that the successful implementation of GBL depends not only on the feasibility and suitability of children’s characteristics but also on the game’s design. Games should be designed with feedback, interactivity, developmentally appropriate challenges, and ensuring that the content and game mechanics are appropriate for children’s abilities [11].

4.3 Effectiveness of game-based learning

After the game was deemed feasible, it was implemented in early childhood to see its effectiveness. The study involved 40 children, divided into experimental and control groups, for 8 weeks. The experimental group used the game application, while the control group followed learning using conventional media.

Table 1 shows the results of the normality test, which is a prerequisite for parametric statistical tests. This normality test uses Shapiro-Wilk. This test was chosen because of its accuracy in assessing normality, especially for smaller sample sizes. In addition, the normality test helps determine whether the data is usually distributed. This information is essential because many statistical analysis techniques require the data to be normally distributed. One can choose the most appropriate analysis technique by knowing whether the normality assumption is met.

Table 1. Normality test results (Shapiro-Wilk test)

Group	Variables	Statistics	df	Sig.
Control	Pre-Difference	0.965	20	0.645
Control	Post-Difference	0.968	20	0.712
Control	Pre-Classification	0.975	20	0.854
Control	Post-Classification	0.973	20	0.816

(Continued)

Table 1. Normality test results (Shapiro-Wilk test) (Continued)

Group	Variables	Statistics	df	Sig.
Control	Pre-Pola	0.962	20	0.583
Control	Post-Pattern	0.966	20	0.667
Control	Pre-Sort	0.970	20	0.784
Control	Post-Sort	0.972	20	0.789
Experiment	Pre-Difference	0.964	20	0.624
Experiment	Post-Difference	0.969	20	0.730
Experiment	Pre-Classification	0.976	20	0.869
Experiment	Post-Classification	0.974	20	0.835
Experiment	Pre-Pola	0.963	20	0.604
Experiment	Post-Pattern	0.967	20	0.690
Experiment	Pre-Sort	0.971	20	0.769
Experiment	Post-Sort	0.973	20	0.816

Based on the Shapiro-Wilk normality test results in the table, the data for all variables in both groups (control and experimental) are typically distributed. This is indicated by the significance values (Sig.) above 0.05, ranging from 0.583 to 0.869. This consistent pattern of significance values demonstrates that the data distribution for all variables, both before (pre) and after (post) treatment, in both groups does not deviate significantly from a normal distribution. Furthermore, the variance homogeneity test was conducted to determine whether the data groups in the study had the same or homogeneous variance. The homogeneity of variances must be tested to ensure the validity of the analysis results and the appropriate interpretation. Interpretation of the homogeneity test results is also necessary to understand its implications for selecting the appropriate method of analysis. Table 2 shows the results of Levene's test between the control and experimental groups.

Table 2. Homogeneity test results (Levene's test)

Variables	F-Statistic	Sig.
Difference	0.124	0.726
Classification	0.018	0.894
Pattern	0.002	0.969
Sort	0.067	0.797

The homogeneity test results using Levene's test demonstrate that the assumption of variance equality between the experimental and control groups is met for all cognitive variables studied. The significance values (Sig.) being considerably higher than 0.05 for each variable indicate no significant variance differences between the two groups. Specifically, the variables Differentiation ($F = 0.124$, $\text{Sig.} = 0.726$), Classification ($F = 0.018$, $\text{Sig.} = 0.894$), Pattern ($F = 0.002$, $\text{Sig.} = 0.969$), and Sort ($F = 0.067$, $\text{Sig.} = 0.797$) all demonstrate homogeneity of variance. These low F-statistics and high p-values confirm that the score variability in both groups is relatively equivalent for each measured cognitive skill. In other words, there are no significant

differences in variance between the experimental and control groups, indicating that both groups have homogeneous score distributions on the cognitive variables. This finding is important because it fulfils the basic assumption for conducting valid comparative analyses between the groups.

After conducting a series of normality and homogeneity tests, the next step is to evaluate the learning intervention’s effectiveness in both groups. The researcher used an independent t-test. The aim was to determine whether there was a significant difference in children’s cognitive ability between the group that received the intervention and the group that followed learning using conventional media.

Table 3. Independent T-test (Control vs. Experiment post-test)

Variables	Lavene’s Test		Independent T-Test				
	F	Sig	t	df	Sig. (2-Tailed)	95% Confidence Interval (CI) of the Difference	
						Lower	Upper
Difference	0.124	.726	-23.237	38	.000	-24.15	-20.32
Classification	0.018	.894	-22.985	38	.000	-23.89	-20.08
Pattern	0.002	.969	-22.156	38	.000	-23.12	-19.45
Sort	0.067	.797	-22.578	38	.000	-23.56	-19.78

Statistical analysis results reveal significant differences between the experimental and control groups across all tested cognitive variables. Levene’s test for equality of variances shows that the assumption of homogeneity of variance is met for all variables ($p > 0.05$), allowing for independent t-tests. The t-test results demonstrate highly significant differences ($p < 0.001$) between the two groups for all cognitive skills: Differentiation ($t = -23.237$), Classification ($t = -22.985$), Pattern ($t = -22.156$), and Sort ($t = -22.578$), with 38 degrees of freedom (df) for each variable. The 95% confidence intervals for mean differences indicate that the experimental group consistently outperformed the control group, with minimum improvements of approximately 19 percentage points and maximum improvements of about 24 percentage points across all skills. This result shows that the game-based learning developed is more optimal in stimulating children’s cognitive abilities compared to conventional learning media used by teachers. This finding aligns with various recent studies in learning technology for early childhood.

This finding is supported by [53], demonstrating that game applications can stimulate various cognitive functions, including attention, problem-solving, and memory in young children. Reinforcing these findings, [30] found that using digital game-based learning can actively strengthen thinking and learning skills at an early age. Furthermore, [15] asserts that apps that focus on creative tasks and problem-solving improve children’s cognitive abilities more than apps that rely solely on memorization. This may explain the advantage of game-based learning in this study, as games involve more creative and problem-solving elements.

These findings are all the more relevant given [34] opinion that many educational apps use teaching methods that are not developmentally appropriate, such as drill methods using flashcards that do not support active learning and creativity. Most currently available educational applications are considered suboptimal in supporting early childhood cognitive development, as they tend only to implement a ‘drill & practice’ approach limited to rote learning without providing more open and explorative

activities [5]. Therefore, the GBL developed in this study was designed by considering the learning principles appropriate to the child’s developmental stage, providing interactive activities that encourage active exploration, problem-solving, and creativity, and integrating fun game elements to maintain children’s learning motivation.

The researcher also analyzed covariance (ANCOVA). This analysis used the post-test score as the dependent variable, the group (experimental vs. control) as the independent factor, and the pre-test score as the covariate. The ANCOVA results can be seen in Table 4.

Table 4. Ancona (analysis of covariance)

Source of Variation	df	F-statistic	P-value	Partial η^2
Pre-test	1	1023.56	< 0.001	0.932
Group	1	2154.89	< 0.0001	0.966
Error	37			

The ANCOVA analysis results demonstrate highly significant effects for both variables studied. The pre-test scores as a covariate strongly impacted post-test results ($F = 1023.56, p < 0.001, \text{Partial } \eta^2 = 0.932$), explaining 93.2% of the variation in final scores. More importantly, the difference between experimental and control groups proved highly significant ($F = 2154.89, p < 0.0001, \text{Partial } \eta^2 = 0.966$), with the new learning method explaining 96.6% of the variation in post-test scores. Both high Partial η^2 values indicate strong effects, with the difference in learning methods having a slightly more significant impact. This suggests that the learning intervention implemented for the experimental group, specifically using game applications designed for cognitive stimulation, had a considerable positive effect on children’s learning outcomes. Such a strong impact implies that GBL strategies can effectively enhance children’s cognitive skills and academic performance, especially in areas like differentiation, classification, pattern recognition, and sorting.

Researchers also used N-Gain (Normalized Gain) analysis to gain a deeper understanding of the effectiveness of the GBL intervention. N-Gain score is calculated by comparing the actual improvement of the child’s score (post-test minus pre-test) with the maximum possible improvement (maximum score minus pre-test). Meanwhile, the N-Gain percent expresses this improvement in percentage form. Table 5 summarizes descriptive statistics from the N-Gain analysis for the entire research sample.

Table 5. Result N-gain

	N	Minimum	Maximum	Mean	Std. Deviation
N-gain_score	40	.63	.97	.8227	.09589
N-gain_percent	40	62.68	96.98	82.2748	9.58942
Valid N (listwise)	40				

After the learning intervention, the N-gain score and N-gain percent analysis showed substantial and consistent improvements in children’s cognitive abilities. With a sample size of 40 participants, the N-gain score ranged from 0.63 to 0.97, with a mean of 0.8227 ($SD = 0.09589$). On average, children’s scores reached 82.27% of their maximum potential improvement. The N-gain percentage, which gives perspective in percentage form, ranged from 62.68% to 96.98%, averaging 82.2748%

(SD = 9.58942). Both metrics confirm the high effectiveness of the learning intervention. The reasonably high minimum values (0.63 for score and 62.68% for percent) indicate that even the children with the lowest improvement still achieved more than half of their improvement potential.

Meanwhile, maximum values close to 1.0 (0.97 for score) and 100% (96.98% for percent) indicate that some children almost reached the maximum improvement. The relatively small standard deviations (0.09589 for score and 9.58942 for percent) indicate the consistency of the intervention effect across the sample. Based on the overall analysis results, it was concluded that the applied learning method was very effective in improving children’s cognitive abilities.

The following two graphs display the results of children’s cognitive ability research. The first graph shows the results from the experimental class, while the second graph presents data from the control class (see Figure 11).

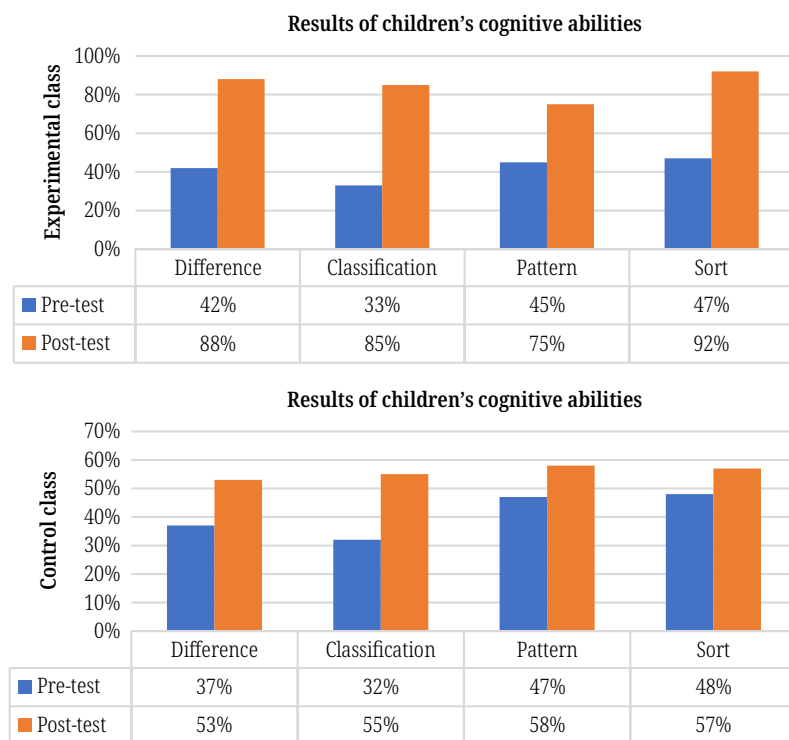


Fig. 11. Children’s cognitive abilities pre- and post-tests in experimental and control classes

The research results show significant differences between the experimental group using the Cognitive Stimulation Game and the control group using traditional learning methods. Overall, the average increase in children’s cognitive abilities in the experimental class was 43.25%. The superiority of the experimental group can be explained through several vital aspects. The Cognitive Stimulation Game presents learning content interactively and through multimedia, providing dynamic visualization and immediate feedback that facilitates more effective concept understanding than traditional methods. The high interactivity of the game, with immediate feedback and opportunities for exploration, encourages active learning and independent discovery. The success of this game in influencing cognitive development is supported by learning principles such as direct experience, scaffolding, active learning, and immediate feedback, all packaged in a format that is enjoyable and appropriate for early childhood learning characteristics.

These findings align with [30] which emphasizes the effectiveness of digital game-based learning in enhancing preschoolers' cognitive skills. This study also strengthens the findings [54], highlighting the role of interactive media in increasing children's motivation and engagement in learning activities. This study significantly contributes to the existing body of knowledge on early childhood education and GBL by introducing the Cognitive Stimulation Game, specifically designed to enhance cognitive skills in young children through engaging and educational activities. Unlike many educational games primarily focusing on entertainment, the Cognitive Stimulation Game integrates a robust educational framework that aligns with developmental milestones and curricular standards for early childhood education. The educational content in applications must align with critical early childhood education processes, ensuring that applications are engaging and educational [55].

However, it is essential to note that this study focused on specific cognitive skills such as classification, pattern recognition, and sorting. While these are essential areas of development, they do not encompass the full range of cognitive abilities children may develop through GBL. As [56] emphasizes, selecting educational apps must consider multiple developmental domains based on age-appropriate content that aligns with established learning theories. This highlights the need for future research to explore a broader spectrum of cognitive skills and their interrelations to provide a more holistic understanding of GBL's impact.

Although these findings are encouraging, addressing several challenges associated with using GBL in ECE is crucial. There are concerns about the increase in screen time and the potential for technology dependency in young children [54]. Recent studies have identified risks associated with excessive screen exposure, including potential adverse effects on sleep patterns, physical activity levels, and face-to-face social interactions. Moreover, researchers have found that extended screen time may impact young children's attention span and executive function development, particularly when screen use exceeds recommended daily limits.

Beyond screen time concerns, implementation challenges also pose significant barriers to effective GBL integration. Comprehensive teacher training is a substantial hurdle [57], as many early childhood educators need more technological literacy and pedagogical knowledge specific to digital learning environments. This training gap often results in suboptimal implementation of GBL strategies, potentially diminishing their educational effectiveness. Teacher attitudes and perceptions also significantly influence the success of GBL implementation. Studies have shown that pre-kindergarten teachers' beliefs about mobile learning's usefulness strongly affect their adoption intentions, followed by their perceived ease of use [58]. However, positive teacher attitudes may not overcome structural barriers such as limited technical support, inadequate infrastructure, and insufficient professional development opportunities.

The digital divide presents another critical challenge, as [59] warns that not all children have equal access to educational technologies and games, which could create inequalities in opportunities for cognitive development. The selection of appropriate educational applications that align with children's developmental stages is crucial in digital learning [15]. Therefore, researchers, educators, mobile developers, and designers must ensure that applications aimed at children have a solid theoretical basis and follow high-quality standards to contribute efficiently to children's developmental progress [5].

Looking toward future developments, the incorporation of emerging technologies such as augmented reality (AR) and virtual reality (VR) into game-based learning presents a promising avenue for research [60], [61]. These technologies can create immersive learning experiences that enhance engagement and interactivity [62], [63].

Future studies could explore how AR and VR GBL can be designed to support cognitive development in young children, examining their effectiveness compared to traditional GBL methods.

Some limitations should be noted. The study involved a relatively small sample size of 40 children divided into experimental and control groups. This limited number of participants may affect the generalizability of the findings. Smaller sample sizes can lead to less robust statistical power, making it challenging to detect significant effects or to extrapolate the results to a larger population confidently. Furthermore, while the study focused on specific cognitive skills such as classification, pattern recognition, and sorting, these only encompass part of the full range of cognitive abilities children may develop through GBL. Future research with a more extensive and diverse sample would help validate our findings. It should explore a broader spectrum of cognitive skills and their interrelations to provide a more holistic understanding of the impact of GBL across different demographics.

5 CONCLUSION

This study highlights the great potential of GBL in enhancing cognitive development in early childhood, suggesting that integrating this method into educational practices can create more engaging and interactive learning environments. To effectively implement these findings, educators must integrate GBL into existing curricula through structured 30-minute daily sessions, with games specifically selected to target cognitive skills such as problem-solving, pattern recognition, and spatial reasoning. Teachers should implement a systematic assessment approach using pre-defined rubrics to measure learning outcomes through gameplay and track student progress. Professional development for teachers should include mandatory 40-hour training programs focusing on game selection criteria, implementation strategies, and assessment methods. Schools should establish mentoring systems and regular peer learning sessions where teachers can share successful GBL practices. Parental involvement should be facilitated through monthly workshops on selecting appropriate educational games and implementing structured home-based learning activities, with clear guidelines for monitoring screen time (maximum 1 hour per day for ages 3–5).

Education policies should support GBL adoption through specific budget allocations for maintaining a 1:4 device-to-student ratio, ensuring stable Internet connectivity with a minimum of 50 Mbps speeds, and establishing technology support systems for maintenance. To address digital equity, policies should include device lending programs and subsidized Internet access for low-income families. Implementing GBL requires interdisciplinary collaboration among educators, developmental psychologists, and game designers, with quarterly collaborative reviews to ensure educational objectives are met while maintaining engagement. School districts should implement standardized GBL integration plans, which include weekly technical support sessions, monthly teacher training workshops, and quarterly assessments of learning outcomes.

To bridge the digital divide, initiatives should provide subsidized devices targeting 80% coverage for low-income families, free Internet access points in community centres, and technical support hotlines in multiple languages. Future research should focus on three-year longitudinal studies tracking cognitive development across different age groups (3–4, 4–5, and 5–6 years), controlled experiments comparing traditional vs. technology-enhanced GBL approaches, and cost-effectiveness analyses of different implementation models. Technology usage guidelines should specify age-appropriate

screen time limits, required physical activity intervals between digital sessions, and recommended digital and traditional learning activities ratios. Furthermore, advanced technology integration research should conduct controlled trials of AR/VR applications in early childhood settings, develop AI-powered adaptive learning systems that adjust difficulty based on individual progress, and study the impact of multiplayer educational games on social skill development. By implementing these specific recommendations and conducting rigorous research, we can ensure that GBL effectively supports children's holistic development in an increasingly digital world.

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7 REFERENCES

- [1] M. M. K. Bruchhage, G. C. Ngo, N. Schneider, V. D'Sa, and S. C. L. Deoni, "Functional connectivity correlates of infant and early childhood cognitive development," *Brain Struct. Funct.*, vol. 225, pp. 669–681, 2020. <https://doi.org/10.1007/s00429-020-02027-4>
- [2] S. M. Hofer and S. Clouston, "On the importance of early-life cognitive abilities in shaping later-life outcomes," *Res. Hum. Dev.*, vol. 11, no. 3, pp. 241–246, 2014. <https://doi.org/10.1080/15427609.2014.936173>
- [3] R. Lamrani and E. H. Abdelwahed, "Game-based learning and gamification to improve skills in early years education," *Computer Science and Information Systems*, vol. 17, no. 1, pp. 339–356, 2020. <https://doi.org/10.2298/CSIS190511043L>
- [4] A. All, E. P. N. Castellar, and J. Van Looy, "Assessing the effectiveness of digital game-based learning: Best practices," *Comput. Educ.*, vol. 92, pp. 90–103, 2016. <https://doi.org/10.1016/j.compedu.2015.10.007>
- [5] S. Papadakis, "Apps to promote computational thinking and coding skills to young age children: A pedagogical challenge for the 21st century learners," *Educational Process: International Journal (EDUPIJ)*, vol. 11, no. 1, pp. 7–13, 2022. <https://doi.org/10.22521/edupij.2022.111.1>
- [6] N. Stiglic and R. M. Viner, "Effects of screentime on the health and well-being of children and adolescents: A systematic review of reviews," *BMJ Open*, vol. 9, no. 1, p. e023191, 2019. <https://doi.org/10.1136/bmjopen-2018-023191>
- [7] S. Domingues-Montanari, "Clinical and psychological effects of excessive screen time on children," *J. Paediatr. Child Health*, vol. 53, no. 4, pp. 333–338, 2017. <https://doi.org/10.1111/jpc.13462>
- [8] R. Flewitt, D. Messer, and N. Kucirkova, "New directions for early literacy in a digital age: The iPad," *Journal of Early Childhood Literacy*, vol. 15, no. 3, pp. 289–310, 2015. <https://doi.org/10.1177/1468798414533560>
- [9] K. Nikolopoulou and V. Gialamas, "ICT and play in preschool: Early childhood teachers' beliefs and confidence," *Int. J. Early Years Educ.*, vol. 23, no. 4, pp. 409–425, 2015. <https://doi.org/10.1080/09669760.2015.1078727>
- [10] Z.-M. Liu, C.-Q. Chen, X.-L. Fan, C.-C. Lin, and X.-D. Ye, "Usability and effects of a combined physical and cognitive intervention based on active video games for preschool children," *Int. J. Environ. Res. Public Health*, vol. 19, no. 12, p. 7420, 2022. <https://doi.org/10.3390/ijerph19127420>

- [11] F. C. Blumberg *et al.*, “Current state of play: Children’s learning in the context of digital games,” *J. Child. Media*, vol. 18, no. 2, pp. 293–299, 2024. <https://doi.org/10.1080/17482798.2024.2335725>
- [12] K. L. Cook and S. B. Bush, “Design thinking in integrated STEAM learning: Surveying the landscape and exploring exemplars in elementary grades,” *Sch. Sci. Math.*, vol. 118, nos. 3–4, pp. 93–103, 2018. <https://doi.org/10.1111/ssm.12268>
- [13] Y.-T. Sung, K.-E. Chang, and T.-C. Liu, “The effects of integrating mobile devices with teaching and learning on students’ learning performance: A meta-analysis and research synthesis,” *Comput. Educ.*, vol. 94, pp. 252–275, 2016. <https://doi.org/10.1016/j.compedu.2015.11.008>
- [14] I. Sarifah *et al.*, “Development of android based educational games to enhance elementary school student interests in learning mathematics,” *International Journal of Interactive Mobile Technologies*, vol. 16, no. 18, pp. 149–161, 2022. <https://doi.org/10.3991/ijim.v16i18.32949>
- [15] M. Kalogiannakis and S. Papadakis, “The use of developmentally mobile applications for preparing pre-service teachers to promote STEM activities in preschool classrooms,” in *Research Anthology on Early Childhood Development and School Transition in the Digital Era*, IGI Global, 2023, pp. 1095–1113. <https://doi.org/10.4018/978-1-6684-7468-6.ch055>
- [16] R. Ramle, S. S. Nathan, and M. Berahim, “Digital game based learning of stack data structure using question prompts,” *International Journal of Interactive Mobile Technologies (ijIM)*, vol. 13, no. 7, pp. 90–102, 2019. <https://doi.org/10.3991/ijim.v13i07.10778>
- [17] N. Behnamnia, A. Kamsin, M. A. B. Ismail, and A. Hayati, “The effective components of creativity in digital game-based learning among young children: A case study,” *Child. Youth Serv. Rev.*, vol. 116, p. 105227, 2020. <https://doi.org/10.1016/j.childyouth.2020.105227>
- [18] E. Yukselturk, S. Altuok, and Z. Başer, “Using game-based learning with kinect technology in foreign language education course,” *J. Educ. Techno. Soc.*, vol. 21, no. 3, pp. 159–173, 2018.
- [19] J. E. Crotty, S. P. Martin-Herz, and R. J. Scharf, “Cognitive development,” *Pediatr. Rev.*, vol. 44, no. 2, pp. 58–67, 2023. <https://doi.org/10.1542/pir.2021-005069>
- [20] H. Aljabreen, “Montessori, Waldorf, and Reggio Emilia: A comparative analysis of alternative models of early childhood education,” *International Journal of Early Childhood*, vol. 52, no. 3, pp. 337–353, 2020. <https://doi.org/10.1007/s13158-020-00277-1>
- [21] D. Neumann, E. R. Peterson, L. Underwood, S. M. B. Morton, and K. E. Waldie, “The development of cognitive functioning indices in early childhood,” *Cogn. Dev.*, vol. 60, p. 101098, 2021. <https://doi.org/10.1016/j.cogdev.2021.101098>
- [22] T. Alzubi, R. Fernández, J. Flores, M. Duran, and J. M. Cotos, “Improving the working memory during early childhood education through the use of an interactive gesture game-based learning approach,” *IEEE Access*, vol. 6, pp. 53998–54009, 2018. <https://doi.org/10.1109/ACCESS.2018.2870575>
- [23] O. A. Hong, N. D. Abd Halim, N. N. Zulkifli, N. F. Jumaat, N. M. Zaid, and M. Mokhtar, “Designing game-based learning kit with integration of augmented reality for learning geography,” *International Journal of Interactive Mobile Technologies (ijIM)*, vol. 16, no. 2, pp. 4–16, 2022. <https://doi.org/10.3991/ijim.v16i02.27377>
- [24] U. Tokac, E. Novak, and C. G. Thompson, “Effects of game-based learning on students’ mathematics achievement: A meta-analysis,” *J. Comput. Assist. Learn.*, vol. 35, no. 3, pp. 407–420, 2019. <https://doi.org/10.1111/jcal.12347>
- [25] S. De Freitas, “Are games effective learning tools? A review of educational games,” *J. Educ. Techno. Soc.*, vol. 21, no. 2, pp. 74–84, 2018.
- [26] D. Hooshyar, M. Yousefi, M. Wang, and H. Lim, “A data-driven procedural-content-generation approach for educational games,” *J. Comput. Assist. Learn.*, vol. 34, no. 6, pp. 731–739, 2018. <https://doi.org/10.1111/jcal.12280>

- [27] J. Paul, "The efficiency of structured spatial skills video game for children-parents and physiotherapist perspective," *Suranaree Journal of Science & Technology*, vol. 29, no. 6, 2022.
- [28] B. Brezovszky *et al.*, "Effects of a mathematics game-based learning environment on primary school students' adaptive number knowledge," *Comput. Educ.*, vol. 128, pp. 63–74, 2019. <https://doi.org/10.1016/j.compedu.2018.09.011>
- [29] D. Tsatsou, N. Vretos, and P. Daras, "Adaptive game-based learning in multi-agent educational settings," *Journal of Computers in Education*, vol. 6, pp. 215–239, 2019. <https://doi.org/10.1007/s40692-018-0118-9>
- [30] N. Behnamnia, A. Kamsin, M. A. B. Ismail, and S. A. Hayati, "A review of using digital game-based learning for preschoolers," *Journal of Computers in Education*, vol. 10, no. 4, pp. 603–636, 2023. <https://doi.org/10.1007/s40692-022-00240-0>
- [31] N. Behnamnia, A. Kamsin, M. A. B. Ismail, and A. Hayati, "The effective components of creativity in digital game-based learning among young children: A case study," *Child. Youth Serv. Rev.*, vol. 116, p. 105227, 2020. <https://doi.org/10.1016/j.childyouth.2020.105227>
- [32] Y. Guan, Y. Qiu, F. Xu, and J. Fang, "Effect of game teaching assisted by deep reinforcement learning on children's physical health and cognitive ability," *Mobile Information Systems*, vol. 2022, no. 1, p. 6150261, 2022. <https://doi.org/10.1155/2022/6150261>
- [33] J. Kesäläinen, E. Suhonen, A. Alijoki, and N. Sajaniemi, "Children's play behaviour, cognitive skills and vocabulary in integrated early childhood special education groups," *International Journal of Inclusive Education*, vol. 26, no. 3, pp. 284–300, 2022. <https://doi.org/10.1080/13603116.2019.1651410>
- [34] S. Papadakis and M. Kalogiannakis, "A research synthesis of the real value of self-proclaimed mobile educational applications for young children," *Mobile Learning Applications in Early Childhood Education*, pp. 1–19, 2020. <https://doi.org/10.4018/978-1-7998-1486-3.ch001>
- [35] K. Nikolopoulou, V. Gialamas, K. Lavidas, and V. Komis, "Teachers' readiness to adopt mobile learning in classrooms: A study in Greece," *Technology, Knowledge and Learning*, vol. 26, no. 1, pp. 53–77, 2021. <https://doi.org/10.1007/s10758-020-09453-7>
- [36] K. Hirsh-Pasek, J. M. Zosh, R. M. Golinkoff, J. H. Gray, M. B. Robb, and J. Kaufman, "Putting education in 'educational' apps: Lessons from the science of learning," *Psychological Science in the Public Interest*, vol. 16, no. 1, pp. 3–34, 2015. <https://doi.org/10.1177/1529100615569721>
- [37] W. W. Lee and D. L. Owens, *Multimedia-Based Instructional Design: Computer-Based Training, Web-Based Training, Distance Broadcast Training, Performance-Based Solutions*. John Wiley & Sons, 2004.
- [38] K. A. Aka, "Integration Borg & Gall (1983) and Lee & Owen (2004) models as an alternative model of design-based research of interactive multimedia in elementary school," *Journal of Physics: Conference Series*, vol. 1318, 2019. <https://doi.org/10.1088/1742-6596/1318/1/012022>
- [39] T. A. Kyriazos, "Applied psychometrics: Sample size and sample power considerations in factor analysis (EFA, CFA) and SEM in general," *Psychology*, vol. 9, no. 8, p. 2207, 2018. <https://doi.org/10.4236/psych.2018.98126>
- [40] NAEYC and Fred Rogers Center for Early Learning and Children's Media, "Technology and interactive media as tools in early childhood programs serving children from birth through age 8," *Joint Position Statement, 2012*. Washington, DC: NAEYC; Latrobe, PA: Fred Rogers Center at St. Vincent College. www.naeyc.org/content/technology-and-young-children
- [41] V. Rideout, "The common sense census: Media use by tweens and teens," 2015.

- [42] S. Papadakis, "The impact of coding apps to support young children in computational thinking and computational fluency. A literature review," *Front. Educ.*, vol. 6, p. 657895, 2021. <https://doi.org/10.3389/feduc.2021.657895>
- [43] N. Iten and D. Petko, "Learning with serious games: Is fun playing the game a predictor of learning success?" *British Journal of Educational Technology*, vol. 47, no. 1, pp. 151–163, 2016. <https://doi.org/10.1111/bjet.12226>
- [44] E. A. Boyle et al., "An update to the systematic literature review of empirical evidence of the impacts and outcomes of computer games and serious games," *Comput. Educ.*, vol. 94, pp. 178–192, 2016. <https://doi.org/10.1016/j.compedu.2015.11.003>
- [45] D. Hooshyar et al., "From gaming to computational thinking: An adaptive educational computer game-based learning approach," *Journal of Educational Computing Research*, vol. 59, no. 3, pp. 383–409, 2021. <https://doi.org/10.1177/0735633120965919>
- [46] B. Zupan, F. Cankar, and S. Setnikar Cankar, "The development of an entrepreneurial mindset in primary education," *Eur. J. Educ.*, vol. 53, no. 3, pp. 427–439, 2018. <https://doi.org/10.1111/ejed.12293>
- [47] C. Hung, J. C. Sun, and P.-T. Yu, "The benefits of a challenge: Student motivation and flow experience in tablet-pc-game-based learning," *Interactive Learning Environments*, vol. 23, no. 2, pp. 172–190, 2015. <https://doi.org/10.1080/10494820.2014.997248>
- [48] M. Bakker, M. van den Heuvel-Panhuizen, and A. Robitzsch, "Effects of mathematics computer games on special education students' multiplicative reasoning ability," *British Journal of Educational Technology*, vol. 47, no. 4, pp. 633–648, 2016. <https://doi.org/10.1111/bjet.12249>
- [49] C.-H. Chen and V. Law, "Scaffolding individual and collaborative game-based learning in learning performance and intrinsic motivation," *Comput. Human Behav.*, vol. 55, pp. 1201–1212, 2016. <https://doi.org/10.1016/j.chb.2015.03.010>
- [50] Y.-M. Huang, S.-H. Huang, and T.-T. Wu, "Embedding diagnostic mechanisms in a digital game for learning mathematics," *Educational Technology Research and Development*, vol. 62, pp. 187–207, 2014. <https://doi.org/10.1007/s11423-013-9315-4>
- [51] P. Drijvers, M. Doorman, P. Kirschner, B. Hoogveld, and P. Boon, "The effect of online tasks for algebra on student achievement in grade 8," *Technology, Knowledge and Learning*, vol. 19, pp. 1–18, 2014. <https://doi.org/10.1007/s10758-014-9217-5>
- [52] P. Siklander, J. Kangas, S. Ruhaalahti, and P. Korva, "Exploring triggers for arousing interest in the online learning," in *INTED2017 Proceedings*, IATED, 2017, pp. 9081–9089. <https://doi.org/10.21125/inted.2017.2150>
- [53] P. A. Howard-Jones, T. Jay, A. Mason, and H. Jones, "Gamification of learning deactivates the default mode network," *Front. Psychol.*, vol. 6, p. 162828, 2016. <https://doi.org/10.3389/fpsyg.2015.01891>
- [54] J. S. Radesky, J. Schumacher, and B. Zuckerman, "Mobile and interactive media use by young children: The good, the bad, and the unknown," *Pediatrics*, vol. 135, no. 1, pp. 1–3, 2015. <https://doi.org/10.1542/peds.2014-2251>
- [55] O. Boude, A. Vargas, and J. Choconta, "Essential features for mobile applications to assist early childhood educators," *International Journal of Interactive Mobile Technologies*, vol. 18, no. 21, pp. 41–58, 2024. <https://doi.org/10.3991/ijim.v18i21.48325>
- [56] S. Papadakis, "Choosing the best educational apps for young children: What parents and educators need to know," in *Desafíos de la inclusión digital: la brecha digital de género y las competencias digitales docentes en el contexto educativo*, Octaedro, 2023, pp. 77–94.
- [57] J. C. Huizenga, G. T. M. Ten Dam, J. M. Voogt, and W. F. Admiraal, "Teacher perceptions of the value of game-based learning in secondary education," *Comput. Educ.*, vol. 110, pp. 105–115, 2017. <https://doi.org/10.1016/j.compedu.2017.03.008>

- [58] S. Papadakis and M. Kalogiannakis, "Evaluating a course for teaching introductory programming with scratch to pre-service kindergarten teachers," *International Journal of Technology Enhanced Learning*, vol. 11, no. 3, pp. 231–246, 2019. <https://doi.org/10.1504/IJTEL.2019.10020447>
- [59] J. Reich, *Failure to Disrupt: Why Technology Alone Can't Transform Education*. Harvard University Press, 2020. <https://doi.org/10.4159/9780674249684>
- [60] J. Garzón, J. Pavón, and S. Baldiris, "Systematic review and meta-analysis of augmented reality in educational settings," *Virtual Real.*, vol. 23, pp. 447–459, 2019. <https://doi.org/10.1007/s10055-019-00379-9>
- [61] N. Pellas, P. Fotaris, I. Kazanidis, and D. Wells, "Augmenting the learning experience in primary and secondary school education: A systematic review of recent trends in augmented reality game-based learning," *Virtual Real.*, vol. 23, no. 4, pp. 329–346, 2019. <https://doi.org/10.1007/s10055-018-0347-2>
- [62] R. M. Yilmaz, "Educational magic toys developed with augmented reality technology for early childhood education," *Comput. Human Behav.*, vol. 54, pp. 240–248, 2016. <https://doi.org/10.1016/j.chb.2015.07.040>
- [63] H. F. Hanafi, K.-T. Wong, M. H. M. Adnan, A. Z. Selamat, N. A. Zainuddin, and M. F. N. Lee Abdullah, "Utilizing animal characters of a mobile augmented reality (AR) reading kit to improve preschoolers' reading skills, motivation, and self-Learning: An initial study," *International Journal of Interactive Mobile Technologies*, vol. 15, no. 24, pp. 94–107, 2021. <https://doi.org/10.3991/ijim.v15i24.26673>

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