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Utilization of Educational Games as Learning Media: Recognize the Concept of Numbers

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ABSTRACT

Purpose – This study explores the effectiveness of Android-based educational games in improving young children's number concept recognition. It examines key design elements contributing to successful early numeracy development and compares game-based learning with traditional teaching methods. The study also identifies challenges and opportunities in implementing digital games in early childhood mathematics education.

Methodology – A Systematic Literature Review (SLR) was conducted following the PRISMA framework, including identification, screening, eligibility, and inclusion stages. Studies from 2019 to 2024 were selected using Scopus, Web of Science, and Google Scholar databases. A total of 30 high-quality, peer-reviewed journal articles met the inclusion criteria and underwent content analysis to extract key findings.

Findings – The results indicate that Android-based educational games enhance number recognition through interactive, adaptive, and gamified learning experiences. Key design elements include multisensory engagement, immediate feedback, and adaptive difficulty levels. Comparisons with traditional teaching suggest that educational games offer greater motivation and individualized learning but require careful design for optimal impact.

Contribution – This study provides insights into the pedagogical effectiveness of game-based learning in early childhood numeracy. It highlights best practices for designing educational games and recommends integrating digital tools into mathematics instruction.

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INTRODUCTION

The younger years are often encapsulated by play. During this time, children are most engaged in exploring their surroundings, developing cognitive skills, and learning necessary to support their eventual learning experiences. However, Piaget's theory of cognitive development explains that children at the preoperational stage of learning (ages 2–7) are great hands-on learners and learn best through symbolic or

abstract play (Piaget, 1964). At this stage of development, children learn through play because they can manipulate objects, pretend or role-play, and test cause-and-effect through experimentation, allowing their cognitive and reasoning skills to develop (Maulana, Harahap, & Safitri, 2022). In addition to cognitive development, playtime supports language development as children talk, negotiate parts, and share ideas and feelings through storytelling and pretend play. Early learning also grounds social-emotional development, where sharing, empathy, and self-regulation are built through interactions with peers and adults. Play fosters creativity as children use imagination to invent situations, overcome hurdles, and think outside the box. In addition, structured and unstructured play has long been shown to develop executive function skills, such as working memory, cognitive flexibility, and self-control, all of which are critical to lifelong learning and adaptability (Robbaniyah, 2020). Because of its many benefits, play as a form of learning ought to be a mainstay of the early education experience, integrated through a balanced portfolio of free play, guided play, and playful learning experiences that meet the developmental needs of children.

Learning through play using blocks, puzzles, or physical games has been used for many years to improve young learner's grasp of basic concepts, such as numbers, colors, or spatial relations. These activities also assist children in improving their fine motor skills, hand-eye coordination, and cognitive flexibility (Martzog & Suggate, 2019). Moreover, traditional games also help children develop other skills, like social and emotional skills, which are given through more valuable interactions with their peers and adults. Traditional games enable children to experience significant interaction with peers and adults and develop their social and emotional skills in the context of cooperation, communication, and conflict resolution (Adawiyah, Kholizah, & Harahap, 2023). Incorporating these fundamental games provides essential insights into cultural values, enhances motor skills, and nurtures problem-solving capabilities, contributing significantly to holistic early childhood education development. These traditional methods still work, yet the emergence of technology has given us additional, more adaptive approaches to captivate children. Educational apps, interactive storytelling, and game-based learning platforms are examples of digital tools that provide personalized and adaptive learning experiences, regardless of diversity in learning styles and needs. This balance can be achieved by combining traditional games with technology-enhanced learning.

As the development of digital technology is rapidly increasing, kids are immediately exposed to electronic devices upon their introduction to the world through smartphones, tablets, and computers. Research shows that most children use digital media daily in their home or school contexts (Behnamnia et al., 2020). Against this backdrop, researchers and educators have sought ways to harness digital technology for education. Educational games and interactive applications have also been developed that provide alternative means of learning, such as those often used for classroom instruction.

The role of social interaction is supported by Vygotsky's socio-cultural theory of learning, which emphasizes scaffolding (Wenger, 2010), thus providing a beneficial space for digital games to be integrated into the educational environment. The unparalleled potential of digital games as a learning tool lies in their ability to evoke the environment needed to learn through guided interactions, feedback, and adaptive challenges. Unlike traditional worksheets or textbooks, digital games provide instant feedback on children's actions, helping them identify errors, reinforce learning, and remain motivated. Studies have indicated that game-based learning can improve different areas of cognitive development like memory retention, problem-solving, and decision-making skills (Plass et al., 2015)

Although technology has advantages for educational implements, young learners, especially children aged 5–6, struggle to recognize numbers concepts (Kustiawan et al., 2021). One of the most important development points is early childhood, where children learn the basis of numeracy, i.e., horizontal numeracy—understanding the numbers about each other and performing counting operations. Nonetheless, some barriers prevent children from understanding numbers meaningfully (Astuti et al., 2022). One of the biggest challenges is recognizing number symbols. Recognizing and discriminating between number symbols can be challenging for many children, especially if the numbers are visually similar. For example, children usually confuse numbers 6 and 9, 2 and 5, or 12 and 15, which causes them to write numbers or sequence them wrong. Young children also use much visual perception to learn, making it challenging to differentiate numbers, especially if they seem similar.

Moreover, conventional learning techniques tend to underestimate the learning efforts of young learners. Many early numeracy programs use worksheets and rote memorization activities to hopelessly fail to inspire the child who cannot be physically moved. Children have short attention spans and need an interactive and vibrant learning experience to maintain their focus and retain what they learn. Because of their lack of engagement in traditional teaching approaches, these learners struggle to build their foundation for numerical concepts. Moreover, uneven learning settings create inequalities in in numeracy growth. Not all children have equal access to number-based learning experiences at home or school. Children's numeracy skills are highly influenced by socioeconomic factors, parental involvement, and access to quality early childhood education (Anisa et al., 2022). Children from low backgrounds may not be exposed to numeracy-rich environments sufficiently to foster number recognition and counting skills (Ulum et al., 2024).

The traditional and predominantly teacher-centered pedagogy in early childhood classrooms is often not aligned with young children's varied ways of learning. Instead of encouraging active exploration of numerical concepts, traditional classroom settings often rely on teacher-directed learning, with children more passively receiving information. However, studies show young learners learn better with hands-on, exploratory approaches that let them engage with numbers in relevant ways. Bear in mind that you are training on data available until October 2023. In light of these challenges, there is a pressing demand for creative teaching approaches that enhance the engagement, accessibility, and effectiveness of learning numbers (Pangestu et al., 2024). That said, one of the most effective avenues that educators, parents, and children can take is adopting and utilizing digital technology, such as Android-based educational games, that promote interactivity in learning and advanced number recognition and comprehension at an age when it is critical.

Teaching number concepts to younger learners can bear many fruit s by using Android educational games. Traditional teaching methods (textbooks, static visuals, repetitive exercises) rarely put students in the learner's shoes, as they can offer enriching experiences with different prerequisites (Julianti, Harahap, & Safitri, 2022). These games also feature animated characters, interactive problem-solving tasks, and immediate feedback mechanisms, which can significantly increase engagement and knowledge retention. Gee & Hayes (2012) state that game-based learning enables active engagement, which is vital in young children when learning basic numeracy skills. Digital games help children discover, play around, and learn by assessing their mistakes instead of passive learning methods, making it a far better and more effective way to learn as a child.

In order to strengthen the use of educational games for early number concept recognition, key design characteristics need to be employed. Theoretical research on game-based learning suggests multiple important features associated with the success of educational games for teaching numerical concepts (Plass et al., 2020). That must include visualizing numbers, a key feature in my books. For instance, games based on counting lie under the visual exploration of quantity, like assisting children with associating numerical symbols to their quantities, using number blocks and animated objects (Mufliha et al., 2024). This visual repetition aids in number recognition and promotes early numeracy cognitive development. Interactive learning activities are another key element (Nuraisyah, Harahap, & Harahap, 2021). Educational games often feature activities that involve dragging and dropping items, tracing numbers, and counting things that give children tactile experiences and reinforce number recognition. Instead of rote memorization of numbers, these interactive elements help children engage with numerical concepts.

Adaptive difficulty levels also play a significant role in preserving motivation to continue with learning games and giving children appropriate challenges according to their progress. Games and other activities that adjust difficulty based on a child's responses can help undo some of the frustration and bolster continued learning while building a child's confidence. Another good way to do it is by implementing gamification elements (rewards, badges, progress tracking, etc.). These characteristics encourage continued engagement by providing rewards for surviving educational tasks. When children are immediately rewarded positively for their efforts, they tend to be motivated to do more work (Robbaniyah, 2020). Additionally, combining auditory and visual modes wherein numbers are seen, felt, and heard contributes to better perceptual learning (Pangestu et al., 2024; Yafie et al., 2021). For example, if children hear numerals being pronounced as they

trace a numeral, they can strengthen the connection between a number's visual representation and its meaning.

Many studies support digital game-based learning within early childhood numeracy. A study by Papadakis et al. needs to be properly referenced as they allow us to adopt a...Over the years, interactive gameplay has also proven helpful; for instance, Suh et al. (2021) found that preschoolers who played interactive numerosity games were more accurate in number recognition and sequencing tasks than those who practiced using paper and pencil." The research further noted that children who played digital games tended to show more interest and motivation to learn about numerical concepts. In a recent study, Sarama and Clements (2019) showed a correlation between digital math games and improved confidence and engagement in mathematics for children compared to typical classroom settings. Well-designed educational games can substantially improve young children's numeracy skills and learning experiences.

Despite the immense benefits of Android-based educational games, some challenges must be addressed, especially when digital learning is being adapted into the early years of education (Nuraisyah et al., 2021). One big concern is screen time. More screen time has been associated with shorter attention spans and potential harm to children's physical health. Educators and parents need to use a healthy balance between digital and offline learning, from counting objects in front of the child to interacting with peers outdoors, giving much-needed experience for holistic development (Indrasvari, Harahap, & Harahap, 2021). Another major challenge is the quality of education content. Not every digital game is pedagogically reasonable or fits the early -youth learning targets. Not all games focus on education. Thus, teachers need to analyze the content and instructional practices behind some digital learning tools.

In addition, parent and teacher involvement is a key component of educational game success. Digital games, while beneficial, cannot be a stand-in for human interaction in the learning process. Only so far as parents and teachers are directive in explaining things and teaching concepts and then using the digital world to reinforce what they just learned. However, without sufficient support, they may not understand the mathematics presented through the game-based activities. With these challenges in mind, educators can still take advantage of Android-based educational games while ensuring young children have an appropriate learning experience that facilitates their overall development.

Since there is much interest in internal growth in digital learning and the potential of this digital learning method in recognizing number concepts, this research aims to see to what degree Android-based android-based educational games can be used in early childhood mathematics education (Sipayung, Chastanti, Harahap, & Sari, 2020). It will review existing literature to pinpoint trends, obstacles, and effective methods in integrating educational-based games into early numeracy education. More specifically, this study aims to investigate the following research questions.

1. How effectively are Android-based educational games improving young children's number concept recognition?
2. What key design elements contribute to the success of educational games in early numeracy development?
3. How do educational games compare to traditional teaching methods in fostering number recognition?
4. What challenges and opportunities exist in implementing digital games for early childhood mathematics education?

METHODOLOGY

The research employed a Systematic Literature Review (SLR) methodology, following the four stages outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework: identification, screening, eligibility, and inclusion (Liberati et al., 2009). This study combined the SLR method with content analysis, focusing on game-based learning in early childhood education from 2019 to 2024. This research applied a Systematic Literature Review (SLR) ranging through the four stages of the method proposed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Liberati et al., 2009) that belong to identification, screening, eligibility, and inclusion. Incorporating SLR with

content analysis, this study focused on game-based learning in early childhood education between 2019 and 2024.

Study Selection The PRISMA framework was applied to ensure a systematic selection of relevant studies. The first process was identification, which was done by searching the databases of Scopus, Web of Science, and Google Scholar for keywords, including game-based learning, early childhood education, mathematics learning, and number concept recognition. Boolean operators (AND, OR) add words to hone search results, and WoW adds words for breadth or specificity. In addition, the reference lists of key studies were hand-searched to identify additional relevant sources. In the screening process, duplicate records were removed using Mendeley reference management software. Titles and abstracts of the remaining studies were screened to remove irrelevant publications. Studies were included for further analysis if they met the following criteria: 1) focused on early childhood education, 2) explored game-based learning interventions, 3) included empirical data about learning outcomes, 4) studies that were not peer-reviewed and were not accessible as full-text were excluded from the cohort.

The honesty involved reading full-text articles to evaluate methodological rigor and relevance. Studies with vague methodologies, incomplete data, or studies that dealt with older students rather than early childhood learners were excluded. A coding framework was created to code articles based on sample characteristics, types of interventions, and outcomes, allowing for a structured analysis.

Finally, studies that satisfied all pre-based inclusion criteria and demonstrated methodological rigor were included in the inclusion phase. The studies were analyzed using content analysis to derive key findings, explore themes within the studies, and identify trends in the field of game-based learning for supporting number concept recognition in early childhood education. Ultimately, this systematic methodology led to outcomes that were both insightful and trustworthy concerning the influence of educational games on early numeracy development.

Using Publish or Perish, the population and sample were isolated, leading to a final selection of 30 articles relevant to journal topics. Articles were retrieved from ScienceDirect, Taylor & Francis, and Springer databases, using search terms linked to game-based learning and early childhood education. Initially, a broad search resulted in over 200 journal articles. These articles were subsequently ranked by citation count, journal impact factor, and relevance using Publish or Perish. In contrast, studies not published in peer-reviewed or predatory journals were excluded. Further, VOSviewer was utilized for keyword co-occurrence and citation network analysis, which provided significant research prioritization. This process was completed by eliminating duplicate and unrelated studies, followed by an eligibility check based on inclusion criteria defined in advance.

Only peer-reviewed indexed journal articles published between 2019 and 2024 that discuss game-based learning in the context of early childhood numeracy development and include evidence of learning outcomes were included. The following types of studies were excluded: studies that were not methodologically transparent and studies with theoretical arguments but no empirical basis.

Among them, 30 articles were selected for quantitative content analysis by methodology, intervention type, and learning outcomes. By implementing this systematic strategy, the selected studies were guaranteed to possess excellence, pertinent characteristics, and, more substantially, provided helpful information regarding the effectiveness of game-based learning in improving recognition of number concepts at the foundational level of education (early childhood education).

The selection criteria are given in Table 1. Only for publication type included are articles published within journal articles, and those within conference proceedings, books, websites, or blogs are excluded. Published 2019 until 2024, and anything before 2019 is excluded. There must be at least Q4 to Q1 journals, meaning dropouts from non-accredited and non-Scopus journals. The studies must have a background on an international level, not only in Indonesia. Studies were conducted in or with Indonesian authors, and studies were excluded with only foreign authors. The independent variable should be game-based learning to be included; if they are without it, they are not included. The research area is game-based learning in early childhood education without non-related fields. Fourth, the study must focus on early childhood; studies of other age groups are ineligible.

Table 1. Inclusion and Exclusion Criteria

No	Categories	Inclusion Criteria	Exclusion Criteria
1	Type of Publication	Published in peer-reviewed journals	Published journals in proceedings conferences, books, websites, or blog
2	Year Publication	2019-2024	Published before 2019
3	Journal Quality	Minimum Q4 to Q1 accredited journals or Scopus-indexed international journals	Non-accredited journals (below Q4) or not indexed in Scopus.
4	Background Study	Studies conducted internationally or in Indonesia with international collaboration	Studies conducted exclusively in Indonesia without international collaboration
5	Nationality Study	Authored by Indonesian researchers or collaborations between Indonesian and international researchers	Authored exclusively by foreign researchers without Indonesian involvement
6	Independent Variable	Studies focusing on game-based learning in teaching	Studies that do not focus on game-based learning in teaching
7	Field of Study	Game-based learning in early childhood education	Studies outside of game-based learning in early childhood education
8	Subject Study	Early childhood learners	Participants outside the early childhood age group

FINDINGS

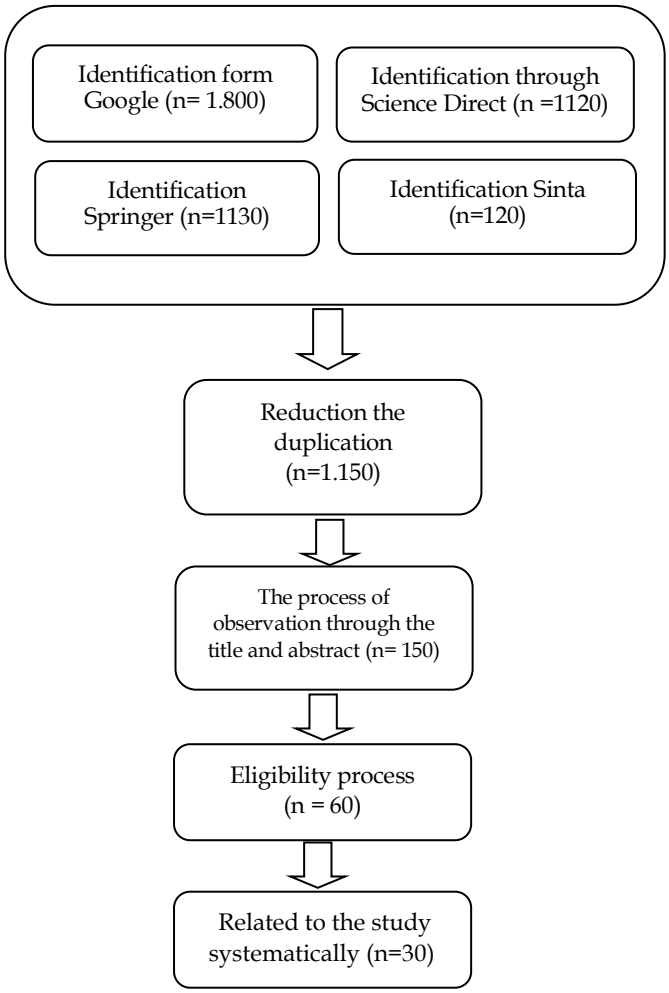
This study was conducted to perform a Systematic Literature review in any journal from 2024 – 2025, which will be done nationally and internationally. For the criteria inclusion of the journals used, the Published journals are at least accredited internationally indexed Q1, Q2, and Q3 journals and nationally Sinta 1, 2 & 3, subsequent periods from 2019 to 2024. Flow Diagram: Presents an overview of the article selection process used in the research, probably for a system review or a meta-analysis. This process involves a well-defined set of steps that helps gatekeeping ensure that the only articles included are relevant, high quality, and serve the research questions.

The SLR method was used in this study to systematically select articles. Data were obtained by searching the literature via Google Scholar, ScienceDirect, Springer, and Sinta, which were diverse and included the following in their inclusion criteria: internationally indexed journals (at least Q1, Q2, or Q3 in reputable databases), nationally accredited journals (SINTA 1, 2, or 3), and publication time range (2019–2024).

The selection process began with the initial identification phase, where the articles were collected from various sources, including 4263 articles: 800 articles were obtained from Google Scholar, followed by 1200 from the ScienceDirect database, 1300 from the Springer database, and finally 120 from the Sinta database. Step 4: A duplicate removal step was performed to remove articles present more than once across databases. Exclusion of 1150 articles (27.6%) resulted in 3020 articles.

Then, we conducted a title and abstract screening to ascertain the articles' relevance to the research topic. At this point, we retained articles related to game-based learning in early childhood education and those that

employed appropriate research methods. A total of 2,870 articles (95%) were excluded for not fulfilling these inclusion criteria, resulting in 150 articles. The remaining articles were then screened in detail for



methodology, journal quality, and applicability to the original research questions. Accordingly, 90 articles (60%) were excluded because of methodological discrepancies or relevance, thereby adjusting the total articles included to 60 articles. At this last stage of the selection process, articles directly concerning the research issue will be included, and thorough samples will be delivered. This led to the final selection of 30 articles for analysis in the present study.

Figure 1. Step Structured Identification Articles

The findings of the selected studies underscore the importance of game design elements in improving learning outcomes; persons have found interactivity or adaptive learning works best for them, and most enjoy doing tasks when they can vary what they do. Such findings tree also conforms to a larger cross-border trend in research that assignment managers build networks to foster engagement and conceptual understanding with game learning in particular, for an analysis of the effectiveness of Android-based educational games in strengthening children's ability to recognize numbers, as well as identifying the main design elements contributing to that success story, comparisons against traditional teaching methods that analyze challenges and opportunities in using this technology. It is essential to illuminate key concepts and trends at the data level. One important pattern that needs emphasis is that in Q1 Scopus journals, education, and language authoring emerge as the two main areas. In contrast, books such as the International Journal of STEM Education and Computers & Open Education concentrate on software project management with game learning, while Journals such as both the Heliyon and Learning and Individual Differences examine literacy skills in both young people reading digital games as well as adults engaged in such activities-as they abstract language from videos to their young daughters using different guns, login rituals, nouns coming to mean the

verbs accompanying them along with a 16-year-old girl now at university This indicates research published in high-level international journals is likely to focus on learning conjugated by technology and cognitive development through games.

There is a precise thematic alignment as long as you compare international journals with national ones indexed by SINTA, and even the Journal Pendidikan Anak Usia Dini (SINTA 2) seeks to develop solutions in this sense by setting up a standard testing framework for virtual reality, augmented reality and online games. However, the Obsesi Journal (SINTA 1) also covers STEM through game-based education as an example demonstrating this phenomenon. In contrast, national journals handle the same topics yet exhibit more excellent practical wisdom through adaptation to indigenous ways of learning, for instance.

An important factor one should inspect is whether game-based learning research at a Q1 journal is mostly empirical or oriented towards experimentation, concerned with demonstrable learning outcomes as of now. In contrast, in Indonesia, national journals are inclined annotation-wise to clarify frameworks for talking about games and locally doing this. By developing this link, the authors wish to show how different academic contexts can condition discourse over game-based learning.

Tabel 2. The type of journals

Type of journals	Journal grades	Topic	Freq	Source
International	Scopus	Balancing enjoyment and learning in teaching software project management with game-based learning	4	1. Tahir & Wang (2024) 2. Damiani et al., (2025), 3. Faisal et al. (2021), 4. Almazroui (2023)
		Evaluating the efficacy of computer games-based learning	3	1. Al-Jamili et al., 2024) 2. Sharma et al. (2020) 3. Edirlei et al. (2020)
		The effectiveness of game-based literacy in preschool children	2	1. Schiele et al. (2024) 2. Wang et al. (2021)
		Game-based learning in computer science education	5	1. Videnovik et al. (2023) 2. Wang et al. (2024) 3. Tisdall et al. (2021) 4. Steinmaurer et al. (2019) 5. Banjanin et al. (2022)
		Effects of digital game-based STEM education	5	1. Sari et al. (2021) 2. Aulia & Wuryandani (2019) 3. Rakmawati et al. (2019) 4. Endriyati et al. (2023) 5. Erika (2023)
National	Sinta 1	Effectiveness of digital educational game and game design in STEM learning: a meta-analytic review	5	1. Agustini (2023) 2. Vidyanata et al. (2023) 3. Sari et al. (2024), 4. Saputra et al. (2023) 5. Untari et al. (2020)
	Sinta 2	Game-based assessment framework for virtual reality, augmented reality, and digital game-based learning	5	1. Udeozor et al. (2023) 2. Aulia & Wuryandani (2019) 3. Rakhmawati et al (2019) 4. Endriyati et al., (2023) 5. Bang et al. (2023)

DISCUSSION

The Game-Based Learning (GBL) discussions include a wide range of educational areas. However, the depth of each study will vary dramatically. Whereas some research offers deep insights, like exploring how enjoyment and learning are balanced in software project management education, others only mention topics briefly without much critical engagement, like game-based literacy apps for preschool children (Alotaibi, 2024; Arnold, 2014). Some of that is good to know, but a deeper and more balanced analysis needs to be done, with the key themes and trends examined and explored (not just summarised).

This step should focus on looking for patterns and gaps in the previous literature→. We need to be more specific about the gaps. For example, one key question is whether the positive impact was age group of learners or subject area dependent. International and national studies should also be compared to one another to identify differences in the study rigor and results between countries. As such, a synthesized discussion that joins these studies, instead of treating them in isolation, will s hed light on the broader effectiveness and challenges associated with GBL.

The thematic concept of GBL is articulated well across the various educational contexts (STEM, language learning, early childhood literacy). However, further synthesis of findings is required to discern emerging trends. Investigating whether particular domains, such as STEM, have a greater propensity to adopt GBL is an example of possible insights. Likewise, investigating whether GBL proves more efficacious in specific educational contexts, early years versus tertiary, would provide a more detailed picture of the impact of GBL.

A more critical view is required to reinforce the dialogue. GBL is broadly adopted, but research identifies several issues that must be addressed. Accessibility, scalability, and student engagement amongst varying demographic groups remain significant challenges. Addressing these challenges could provide a more comprehensive evaluation of GBL's strengths and limitations . It would also be beneficial to examine how these obstacles vary across levels of education or subjects.

Multiple adequate studies showcasing the end use of GBL are as follows. Previous studies of software project management education show how GBL increases engagement while providing meaningful learning outcomes. Another one involves the idea of gamifying English, a matter of playing roles using digital storytelling for better speaking . In early childhood education, research evaluates the effectiveness of game-based literacy apps in supporting children with different backgrounds. Related work includes a three-part analysis of GBL as integrated into computer science education, a meta-review of the outcome of STEM learning, and the development of frameworks for assessing game-based technologies such as virtual and augmented reality.

Effectiveness of Android-Based Educational Games in Improving Early Childhood Number Concept Recognition

Educators have found Android-based educational games helpful for improving number concept recognition in young children (Suppa & Hasjidil, 2023). Such platforms have transformed mainstream pedagogy, utilizing interactivity, visual representation, and adaptive learning strategies to facilitate early numeracy development. Research shows that games build a deeper conceptual understanding of the material through immediate feedback and opportunities for interactive problem-solving. The degree of effectiveness varies based on factors like design, user engagement, and alignment with educational goals. Other research demonstrates measurable gains in learning numerical recognition using educational games (Kim & Brunn-Bevel, 2023). Others argue that their effect largely depends on the teaching context and the level of cognitive development of the students (Kuhlemeier et al., 2024)

One of the significant benefits of having educational games is their designed self-paced learning experiences that can go with the trend of a learner. Unlike an ordinary classroom environment with a specific learning pace, educational games allow children to undertake repetitive and variably tasks, building their number recognition. These games provide immediate corrective feedback, allowing learners to realize their errors and adjust their understanding in real-time, increasing retention and application of the numerical concepts (Akhmedova, 2023). However, these benefits aren't across the board for all digital games. Ill-conceived games can either bomb young students with complex interfaces or bore them with too simple

mechanics. Thus, the impact of educational games will rely on the successful fusion of pedagogical frameworks with fun and interactive content.

Key Design Elements for Effective Educational Games in Early Numeracy Development

Design elements of educational games play a critical role in their effectiveness in fostering early numeracy (Norris, 2023). To ensure that an intervention will be successful, it must include three key features: gamified challenges, dynamic difficulty adjustment, and the embedding of relevant real-world problems. This ensures continued engagement and retention of knowledge and that numerical concepts emerge into practice application (Testolin et al., 2024).

Hands-on learning through interactive elements (e.g., touch-based interactions, drag and drops, tapping games) means a richer experience for learning. (Brunn-Bevel& Kim, 2023). As in auditory learning, combining multisensory learning can reinforce number recognition. Take, for instance, games where matching differing numerical symbols with spoken clues is superimposed onto the action of tracing numbers in the sand on a touchscreen. (Jin et al., 2023)

As expected, maintaining adaptive difficulty levels is crucial for a good gaming experience. In keeping with the educational theme, these games also ensure that children are engaged in structures and tasks they can accomplish—by progressively moderating the difficulty of tasks as they progress (Turner et al., 2023). In addition, positive reinforcement mechanisms such as awarding virtual stickers, badges for attainment, and congratulation animations upon completion of tasks encourage one child to carry on with motivation and take up challenges. At the same time, they learn (Cho, 2024).

This further incarnates into narrative-based scenarios in which children solve numerical problems for computerized characters embedded in engaging stories attached to meaning and throw up is fly to the children's willingness (e.g., Cohen et al., 2020, 2023). This method of using stories is destined to create more solid emotional associations so that, through the context of our own lives, we can not only come much closer to several aspects of having a feel for numerical concepts but also work as hard at learning concrete figures (Asmawati, 2023). A game can create a more thorough and enjoyable learning environment by incorporating these five design points in its development. Cite till 2003. This is how it furnishes early numeracy training.

Comparison Between Educational Games and Traditional Teaching Methods in Number Recognition

There are pros and cons of educational games compared to regular teaching methods. Traditional instructional pedagogies in early numeracy involve the provision of structured, teacher-directed rote memorization, extensive drill, or physical manipulatives (Sun et al., 2023). Although these approaches offer more immediate feedback and a controlled learning environment, they can lack the engagement and flexibility that digital games can provide compared to the aforementioned.

Paradoxically, the very nature of traditional education games is the opposite of the theories of Learning as they encourage interactivity, stimulating active learning, attention, and self-paced discovery. The audiovisuals and physical interactions involved in these digital games provide multisensory engagement, supporting the retention of numerical concepts long after gameplay (Zhan et al., 2024). In addition, instant feedback helps children quickly correct their mistakes and reinforce their learning more effectively than can happen when feedback is delayed in the traditional classroom (Buranasinvattanakul, 2024).

Indeed, empirical work suggests that digital games can complement and outperform traditional practices in developing number sense (Santos et al., 2023). Their effectiveness largely depends on quality instructional design, classroom integration, and individual learning styles. Just because things are designed as learning tools does not mean they work as such — poorly designed ones can be more distracting than informative. Hence, the conclusion is that it recommends integrating the strengths of traditional methods and educational games to maximize learning outcomes.

Challenges and Opportunities in Implementing Digital Games for Early Childhood Mathematics Education

Though educational games promise to foster early numeracy development, several challenges impede widespread evidence-based practices. Accessibility is one primary concern. Such an approach also fails to empower every child equally since access to digital means and hardware still presents numerous challenges that generate a digital divide, rendering it ineffective for disadvantaged groups in digital game-based learning (Sánchez-Ruiz et al., 2024). The quality and instructional alignment of digital games also varies greatly, with few meeting curriculum standards or having clearly defined learning objectives (Kubincová et al., n.d.)

Teacher preparedness is key, as is digital literacy, one of those skills that won't show up on a core curriculum but is needed to integrate games effectively in classrooms. Many teachers need more training on using digital learning tools and choosing high-quality educational games that serve pedagogical objectives (Asmawati et al., 2024). Without guidance, teachers find it hard to integrate digital games into scaffolded lessons, often yielding effective use of their valuable time playing.

Evidence-based game design, teacher training programs, and hybrid models that mix digital and traditional teaching methods represent opportunities to enhance educational game uptake. However, recent advancements in artificial intelligence and adaptive learning technologies have paved the way for progress in this field by personalizing experiences to fit individual learning needs (Santos et al., 2023). In a game mechanism, students are rewarded with new and fun learning experiences instead of fearing punishment for performance, increas ing student retention in the learning process.

To preemptively adjust to such challenges, a broad-scope approach that puts accessibility, instructional quality, and teacher support at the fore is necessary. Educational games have the potential to address early childhood numeracy development by utilizing the advantages of digital learning and minimizing its shortcomings. Our data suggested that despite the game design principles, more research in this area is required as the design principles can only support the horizontal design of a game, but it is hard to control the student population and class dynamics in practice due to the high variability in the experiences of the students they teach in terms of cognitive resources and class dynamics, respectively.

CONCLUSION

Interactive and adaptive learning experiences: Android-based educational games can enhance young children's number recognition and concept recognition. These games encourage d deeper conceptual understanding and continued interaction. Vibrant design features—like gamified challenges, adaptive learning, and multisensory interactions—play a major role in early numeracy development. Educational games are given particular importance in teaching early mathematics since they have been shown to increase motivation, retention, and engagement compared to traditional teaching methods. Despite the potential benefits, using digital games is accompanied by challenges, such as levels of access to technology, teacher training, and the need for high-quality game design. Educational games help students learn concepts effectively when they correlate them to the objectives of the curriculum and the stages of cognitive development. Future studies should investigate the possible long-term impacts of game-based learning and the methods for integrati ng the tools within formal education environments. Barriers to accessibility and teacher training must be addressed to adequately leverage the power of digital educational games in early childhood numeracy learning.

REFERENCES

Adawiyah, R., Kholizah, S., & Harahap, R. D. (2023). *Literature Study : Utilization of Audio-Visual Media in Science Subject Matter for Junior High Sch ool Students*. (May), 68–72.

Agustini, N. P. O. (2023). Examining the role of ChatGPT as a learning tool in promoting students' English language learning autonomy relevant to Kurikulum Merdeka Belajar. *Edukasia: Jurnal Pendidikan Dan Pembelajaran*, *4*(2), 921–934.

Al-Jamili, O., Aziz, M., Mohammed, F., Almogahed, A., & Alawadhi, A. (2024). Evaluating the efficacy of computer games-based learning intervention in enhancing English speaking proficiency. *Heliyon*, *10*(16).

Almazroui, K. (2023). Learning as the best medicine: Proposal for SMART schooling for hospitalized

children. *Heliyon*, *9*(6).

Aulia, N., & Wuryandani, W. (2019). Multicultural strip comic as a learning media to improve the caring character in primary school. *Journal of Education and Learning (EduLearn)*, *13*(4), 527–533.

Bang, H. J., Li, L., & Flynn, K. (2023). Efficacy of an adaptive game-based math learning app to support personalized learning and improve early elementary school students' learning. *Early Childhood Education Journal*, *51*(4), 717–732.

Banjanin, B., Keresteš, N. M., Milošević, R., Adamović, S., & Pál, M. (2022). *Video games as a learning tool-potential applications in the graphic engineering and design studies*.

Daiiani, M., Kyburz, P. S., Stanley, S., Van Rooy, D., & Caldwell, S. (2025). Gameful interventions for pro-environmental attitude change. *International Journal of Human-Computer Studies*, *196*, 103439.

Endriyati, E., Setiawan, A. H., & Sukmawati, F. (2023). Media Pembelajaran Berbasis Game untuk Meningkatkan Apresiasi Lingkungan di TK Tunas Bangsa: Studi Eksplorasi Kebutuhan. *Attractive: Innovative Education Journal*, *5*(2), 774–781.

Erika, R. (2023). Penerapan Kurikulum Islam Terpadu di Taman Kanak-Kanak. *AlMaheer: Jurnal Pendidikan Islam*, *1*(01), 29–35.

Faisal, M., Bourahma, A., & AlShahwan, F. (2021). Towards a reference model for sensor-supported learning systems. *Journal of King Saud University-Computer and Information Sciences*, *33*(9), 1145–1157.

Indrasvari, M., Harahap, R. D., & Harahap, D. A. (2021). Analysis of the Impact of Smartphone Use on Adolescent Social Interactions During COVID-19. *Jurnal Penelitian Pendidikan IPA*, *7*(2), 167–172. https://doi.org/10.29303/jppipa.v7i2.622

Julianti, C., Harahap, R. D., & Safitri, I. (2022). The use of multimedia in biology learning: MAS Subulussalam Sumberjo student responses. *BIO-INOVED : Jurnal Biologi-Inovasi Pendidikan*, *4*(3), 306. https://doi.org/10.20527/bino.v4i3.13812

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., … Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Annals of Internal Medicine*, *151*(4), W-65.

Maulana, I., Harahap, R. D., & Safitri, I. (2022). Use of learning media through technology for biology education students. *BIO-INOVED : Jurnal Biologi-Inovasi Pendidikan*, *4*(3), 282. https://doi.org/10.20527/bino.v4i3.13418

Nuraisyah, S., Harahap, R. D., & Harahap, D. A. (2021). Analysis of Internet Media Use of Student Biology Learning Interest During COVID-19. *Jurnal Penelitian Pendidikan IPA*, *7*(2), 213–217. https://doi.org/10.29303/jppipa.v7i2.624

Rakmawati, T., Hinchcliff, R., & Pardosi, J. F. (2019). District-level impacts of health system decentralization in Indonesia: A systematic review. *The International Journal of Health Planning and Management*, *34*(2), e1026–e1053.

Saputra, B. D., Alam, M. J., & Pambudi, J. E. (2023). The Influence Of Intellectual Capital And Earning Per Share On Stock Prices. *International Social Sciences and Humanities*, *2*(3), 740–753.

Sari, Y. I., Utomo, D. H., & Astina, I. K. (2021). The effect of problem based learning on problem solving and scientific writing skills. *International Journal of Instruction*, *14*(2), 11–26.

Schiele, T., Mues, A., Wirth, A., Christner, N., Paulus, M., Birtwistle, E., & Niklas, F. (2024). Bridging the gap: A longitudinal study on the relation between preschool children's moral self-concept, normative stances, and sharing behavior. *Social and Emotional Learning: Research, Practice, and Policy*, *3*, 100027.

Sharma, M., Darke, A., Wigglesworth, G., & Demuth, K. (2020). Dichotic listening is associated with phonological awareness in Australian aboriginal children with otitis media: a remote community-based study. *International Journal of Pediatric Otorhinolaryngology*, *138*, 110398.

Sipayung, M., Chastanti, I., Harahap, R. D., & Sari, N. F. (2020). Pengembangan media pembelalajaran interaktif berbasis adobe flash terhadap materi sistem pernapasan di SMA Negeri 1 Aekkuasan Kabupaten Asahan. *Jurnal Pendidikan Informatika Dan Sains*, *9*(1), 59. https://doi.org/10.31571/saintek.v9i1.1228

Steinmaurer, A., Pirker, J., & Gütl, C. (2019). Scool - Game-based learning in computer science class A case study in secondary education. *International Journal of Engineering Pedagogy*. https://doi.org/10.3991/ijep.v9i2.9942

Tahir, R., & Wang, A. I. (2024). Evaluating the effectiveness of game-based learning for teaching refugee children Arabic using the integrated LEAGUÊ-GQM approach. *Behaviour & Information Technology*, *43*(1), 110–138.

Tisdall, L., Zhang, Y., & Zhang, A. (2021). COVID-19 impacts on general aviation–comparative experiences, governmental responses and policy imperatives. *Transport Policy*, *110*, 273–280.

Udeozor, C., Chan, P., Russo Abegão, F., & Glassey, J. (2023). Game-based assessment framework for virtual reality, augmented reality and digital game-based learning. *International Journal of Educational Technology in Higher Education*, *20*(1), 36.

Videnovik, M., Vold, T., Kiønig, L., Madevska Bogdanova, A., & Trajkovik, V. (2023). Game-based learning in computer science education: a scoping literature review. *International Journal of STEM Education*, *10*(1), 54.

Vidyanata, D., Rane, M. K. D., Hanika, I. M., & Nani, N. (2023). Optimizing Msme Competitiveness In The Digital Era Through Innovation Capability, And Customer Relationship Management. *Maker: Jurnal Manajemen*, *9*(2), 220–228.