Impacts and Factors of Using Digital and AR Games in Mathematics Education: Findings from Experimental Research in Primary Schools in Vietnam

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ABSTRACT:

The present article explores the impacts and factors influencing the effectiveness of digital games and augmented reality (AR) games in mathematics education for primary school students. The study employed a mixed-methods approach, incorporating quantitative data from mathematics test results and survey responses, as well as qualitative data from classroom observations and interviews with teachers and students. The research involved 168 teachers conducting 168 experimental classes from different regions of Vietnam. The investigation focused on the effects of digital and AR games on students' academic performance, skill development, engagement, and motivation in mathematics. Additionally, it examined the influence of factors such as gender and geographical location on the effectiveness of these games in teaching mathematics. The findings offer valuable insights into the potential benefits, influencing factors, and limitations associated with integrating digital and AR games in the mathematics classroom. These insights can inform educators and policymakers in their efforts to enhance the quality of education.

KEYWORDS: *digital games, augmented reality games, mathematics education, primary school, students, teachers*

1. Introduction

Mathematics has long been recognized as a crucial subject for fostering students' problem-solving skills, critical thinking abilities, and cognitive development. However, it is often perceived as a boring subject with strict theories and formulas (Gecu-Parmaksiz & Delialioğlu, 2020). To make Mathematics more engaging and exciting, there has been a continuous effort to innovate teaching methods, particularly by incorporating technology into the classroom. One cutting-edge technology that has gained attention is Augmented Reality (AR), which brings real-world experiences into mathematics education. Previous research has shown that the integration of AR technology in educational settings, including AR games, has

the potential to enhance students' engagement and learning outcomes (Cheng et al., 2020). By overlaying virtual objects in the real-world environment, AR games create an immersive learning environment that promotes active participation, hands-on experiences, visualization of abstract concepts, and immediate feedback.

In Vietnam, there is a growing recognition of the need to adopt innovative approaches to enhance students' mathematical proficiency. However, the use of AR technology in mathematics education remains limited in the country. This study aims to bridge this gap by exploring the perceptions and learning outcomes of primary school students who have been exposed to digital and AR games in their mathematics classes. The research methodology involves quantitative and qualitative data collection from primary school students and teachers, focusing on grade 1 and grade 2 students from different regions of Vietnam. By examining the experiences and perceptions of both students and teachers, this study sheds light on the practical implications and challenges associated with implementing AR technology in the Vietnamese educational context. The findings of this study will contribute to the existing literature by providing empirical evidence on the effectiveness of AR games in mathematics education, specifically in primary schools in Vietnam. The insights gained from this research can inform policymakers, educators, and curriculum developers about the potential benefits and challenges of integrating AR games into mathematics instruction, leading to evidence-based decisions and recommendations for future educational practices. Additionally, the study may serve as a basis for further research and guide the integration of AR technology in primary school classrooms, ultimately enhancing mathematics instruction and student learning outcomes.

2. Literature review

Technologies have transformed various aspects of society, including education, by offering new opportunities for interactive and engaging learning experiences. In the field of mathematics education, the integration of digital and AR games has emerged as a promising approach to enhance student engagement and improve learning outcomes. This literature review aims to examine the current body of research and scholarly works that delve into the effectiveness of utilizing digital and AR games in mathematics education, with a particular emphasis on primary schools.

The impact of digital and AR games on mathematics education

Recent research has provided substantial evidence supporting the effectiveness of integrating digital games and AR games into educational settings, particularly in the domain of mathematics. The interactive and engaging features of digital games have been shown to enhance student motivation, engagement, and learning outcomes (Gee, 2003; Papastergiou, 2009). Moreover, AR games, which overlay virtual content onto the real world, offer students immersive and hands-on learning experiences (Klopfer et al., 2009). Studies in the field have consistently reported positive impacts of digital games and AR games on various educational domains, including mathematics (Chin et al., 2019; Hwang et al., 2016). These games provide opportunities for active participation, problem-solving, and conceptual

understanding, ultimately leading to improved mathematical abilities and higher academic achievement (Desmet et al., 2012; Milgram & Kishino, 1994). The integration of digital games and AR games in education presents immense potential for transforming traditional instructional approaches and creating more engaging and effective learning environments.

In the past decade, extensive research has explored the impacts of incorporating digital games and AR games into mathematics instruction. Several studies have underscored the potential of digital games in promoting student engagement, motivation, and conceptual understanding in mathematics (Baker et al., 2010). For instance, Bai et al. (2016) found that a 3-D instructional game significantly improved mathematics achievement and motivation among middle school students. Similarly, AR games have shown promise in fostering a deeper understanding of mathematical concepts through interactive and immersive experiences (Hainey et al., 2016). Cai et al. (2019) conducted a study involving junior high school students using AR applications on tablets to learn mathematics. The findings indicated that AR applications helped students with higher self-efficacy to focus on higher-level concepts and employ advanced learning strategies. Similarly, Russo et al. (2019) explored the use of digital games in Australian primary school mathematics classrooms and found that games were highly effective in engaging students and developing mathematical proficiencies. Fokides (2018) conducted a study with primary students in Athens, Greece, and demonstrated that students in the games group outperformed their counterparts in other groups when using digital educational games in mathematics. These findings collectively emphasize the potential of digital games and AR games as innovative and effective approaches to teaching mathematics, addressing the need for engaging and interactive instructional strategies.

Furthermore, research has shown that digital and AR games contribute to a deeper conceptual understanding of mathematics. Gargrish et al. (2022) conducted a study evaluating memory retention among students using AR-based geometry learning assistants and found that AR-based learning led to better memory retention compared to interactive simulation-based learning. Hwang et al. (2016) reported that an AR-based gaming method improved students' learning attitudes and outcomes. Su and Cheng (2013a) conducted quasi-experiments and found that a 3D game-based learning system in software engineering achieved better learning achievement and motivation compared to traditional teaching. Freina et al. (2017) investigated the impact of digital games on the mathematics performance of primary school students and found significant improvements compared to traditional instruction, as demonstrated by standardized mathematics tests.

While the use of digital and AR games in mathematics education offers significant benefits, it is important to acknowledge potential challenges and limitations. Excessive reliance on technology can lead to addictive behaviors and may hinder learning outcomes (Kwon et al., 2016). Carr (2012) conducted a quantitative quasi-experimental study examining the effects of iPad use on mathematics achievement in elementary schools and found no significant difference between the experimental and control groups.

In conclusion, integrating digital and AR games into mathematics education shows promise in enhancing students' mathematics performance, improving skills, and deepening conceptual understanding. However, educators should be cautious of challenges such as over-reliance on technology and the need for effective implementation. By addressing these factors, educators can leverage the benefits of digital and AR games to create engaging and effective learning environments that promote students' mathematical proficiency and success.

Impacts on students' skills

The impact of using digital and AR games on students' transferable skills has been an area that has received limited attention in the literature. While research has demonstrated the positive effects of serious games on developing and sustaining 21st-century skills (Romero et al., 201x), further investigation is warranted in this field. Moreover, the study conducted by Hoffman et al. (2021) found that participants with lower levels of motivation for mathematics experienced a significant decrease in their self-perceived ability in math, whereas this was not observed for participants with higher levels of motivation. Papastergiou's (2009) study, for example, revealed that digital mathematics games contributed to improved problem-solving skills and conceptual understanding among primary school students. Similarly, AR games have demonstrated promising outcomes in fostering mathematical thinking and spatial reasoning abilities in early learners (Bacca et al., 2014). Gecu-Parmaksiz and Delialioğlu's (2020) quasi-experimental research conducted with preschool children found that the use of AR-based virtual manipulatives significantly improved spatial skills compared to physical manipulatives. These findings highlight the importance of considering students' motivation levels in relation to the development of transferable skills. Additionally, Nguyen et al. (2019) demonstrated that the use of technology in teaching mathematics resulted in increased interest among students and a perception of enhanced problem-solving abilities. However, more research is needed to explore the specific impact of digital and AR games on students' transferable skills in mathematics education.

The impact of using digital and AR games on students' attitudes, interests, and learning motivation

The use of digital and augmented reality (AR) games in mathematics education has shown considerable potential in shaping students' attitudes toward mathematics, fostering interest, enhancing learning motivation, and promoting engagement. Research has indicated that incorporating digital and AR games in mathematics instruction positively influences students' attitudes toward the subject. Nguyen et al. (2019) investigated the effects of web-based assessment and practice on improving middle school students' mathematics learning attitudes. With the use of an experimental design and a combination of quantitative and qualitative methods, the study indicates that with the opportunities of drilling and practicing on the computer and receiving instant scores and adapted feedback, students had gained interest in doing mathematics and formed a perception that they became smarter in problem-solving. However, the attitude improvements were quite different across

ethnic and gender groups. Within the WP group, while male students gained more confidence than females, females expressed stronger opinions on the fact that instant scores and feedback helped them overcome difficulties in mathematics problem-solving. Furthermore, the integration of game-based learning (GBL) applications using computer technologies on student engagement in secondary school science classrooms based on intervention with a sample of 72 participants of 8th grade in Pakistan following a quasi-experimental research framework and via observing behavior and emotions of the participants during science lessons; and conducting pre and post-tests to assess the learning outcomes of participants The test show that the GBL application has a positive influence on student engagement (Khan et al., 2017). Similarly, Hoffman et al. (2021) found a relationship between elementary students' domain-specific and game-specific motivations in the context of educational video games with the participants of 30 sixth-grade students in two groups based on their level of motivation for the domain of math. Furthermore, research has increasingly explored the integration of digital games and AR games in mathematics instruction within primary schools and for early learners. Studies have investigated the potential of digital games to enhance engagement, motivation, and mathematical learning outcomes among young students (White et al., 2019). The results demonstrated that participants expressed high levels of interest, effort, pressure, and value for the game despite their varied levels of mathematics motivation.

In contrast to the above research, Kebritchi et al. (2010) conducted research on 193 students and 10 teachers with a mixed method of quantitative and interviews, found no significant improvement was found in the motivation of the experimental and control groups.

Factors influencing the effectiveness of digital and AR games in mathematics education

When considering the utilization of digital and AR games in mathematics education for primary school students, various factors come into play. A literature review conducted by Timotheou et al. (2022) revealed that the integration of ICT in schools impacts not only students' academic performance but also other aspects related to schooling. Moreover, research by Nguyen et al. (2019) highlighted the importance of considering ethnic and gender differences. The study found that while male students gained more confidence, female students expressed stronger opinions regarding the benefits of instant scores and feedback in overcoming difficulties in mathematics problem-solving when using digital learning activities. Similarly, Khan et al. (2017) demonstrated that the effectiveness of game-based learning applications varied across students, with girls outperforming boys in terms of engagement and learning outcomes. These findings emphasize the need to develop educational games that cater to the diverse needs and preferences of students. Gender also plays a role in game preferences, as reported by Inal and Cagiltay (2007), who found that male players tend to prefer games with challenge and competition, while female players prioritize narrative and storytelling elements. Additionally, Hoffman and Nadelson (2010) noted that males were more motivated

to play video games and spent more time playing compared to females when gaming orientation was considered. Furthermore, Kebritchi et al. (2010) highlighted that factors such as prior knowledge, computer skills, and English language proficiency did not significantly impact achievement and motivation in the experimental group. Alongside these factors, this study aims to delve into the accessibility and usability of digital and AR games, as well as infrastructure conditions and living areas, which may influence students' assessments of the effectiveness of learning mathematics with these technologies. To address this research gap, the present study conducted experimental research in primary schools across Vietnam, aiming to examine the impact of digital and AR games on student engagement, motivation, and learning outcomes. It also sought to identify the factors that influence their effectiveness, considering the cultural and educational context of Vietnam. The findings from this study will provide valuable insights for educators and policymakers, enabling them to harness the potential of digital and AR games to enhance mathematics education in Vietnamese primary schools and make informed decisions regarding their implementation.

3. Methodology

3. 1. Research questions

The primary aim of this study is to investigate three key research questions related to the integration of digital games and augmented reality (AR) games in mathematics education in Vietnam.

- How does the integration of digital games and augmented reality (AR) games impact students' performance, skill development and engagement and motivation in mathematics education in Vietnam?

- What are the factors influencing the effectiveness of using digital games and AR games in teaching Mathematics?

- What are the potential implications and recommendations for incorporating digital games and AR games effectively in mathematics education in Vietnam based on the experimental assessment?

3.2. Research design

The study will employ an experimental research design, using a combination of qualitative and quantitative research methods, to assess the impact of digital games and AR games in mathematics education in Vietnam. Due to practical constraints and ethical considerations, a non-equivalent group design will be utilized, which is a form of quasi-experimental research. This design allows for the comparison of groups that are not randomly assigned. Ethics approval for this study has been obtained from the Vietnam National Institute of Educational Sciences.

3.3. Research tools

In this experimental study, a variety of research tools will be employed to collect data. These tools include:

1) Lesson plans: Two lesson plans will be developed, one for 1st grade and one for 2nd grade, for the experimental group. These lesson plans will integrate technology by incorporating a combination of digital games and AR games. The lesson plans will be implemented in conjunction with a Learning Management System (LMS) to assess student learning outcomes. The topics covered in the lesson plans include addition within 10 for 1st grade and reading the time, and practicing watching the clock for 2nd grade.

2) Post-lesson test: A mathematics assessment test will be designed to measure students' mathematical knowledge and skills after the intervention. This test will provide quantitative data on the effectiveness of using digital games and AR games in improving student learning outcomes.

3) Classroom observations: Classroom observations will be conducted to gather qualitative data on student behavior, attitudes, and performance during the intervention. Observations will focus on aspects such as student engagement, motivation, and interaction with technology. These observations will provide valuable insights into the impact of digital and AR games on student behavior and classroom dynamics.

4) Surveys and questionnaires: Both teachers and students will be given surveys and questionnaires to gather their perceptions and attitudes towards using digital games and AR games in mathematics education. These surveys will provide insights into the experiences and opinions of both teachers and students regarding the effectiveness and usability of the technology.

5) Teacher interviews: Interviews will be conducted with teachers to explore their assessments of student mathematics performance through the use of technology. These interviews will also aim to understand the factors that influence teachers' opinions and perceptions about the implementation efficiency of digital games and AR games in mathematics education.

6) Student group discussions: Group discussions will be organized with students to gather their perspectives on their mathematics performance and their experiences with using digital games and AR games in the classroom. These discussions will provide additional qualitative data on student assessments and the factors that influence their opinions.

By utilizing these research tools, the study aims to comprehensively explore the impact and factors influencing the effectiveness of using digital games and AR games in mathematics education, as well as gather insights from both teachers and students.

3.4 Research sites and participants

The research was conducted in various primary schools located in urban, rural, and mountainous areas in Hanoi, Dong Thap, and Dak Lak Province. These schools were chosen to represent the three main regions of Vietnam: The North, the Central region, and the South, encompassing diverse economic and geographical conditions. The selection of schools from different localities aimed to ensure a representative sample for Vietnam. In each school, two classes were selected to participate in the study. One

class received mathematics instruction with the use of digital and AR games, while the other class received conventional instruction without the use of technology. The experiment took place during the school year of 2021-2022. The number of participating teachers and students in each location is presented in Table 1.

Table 1. Research sites and sampling

Class	Teachers	Students (total)	Treatment group		Control group	
			Class	Students	Class	Students
Grade 1	68	5780	68	2856	68	2924
Grade 2	100	8097	100	4059	100	4038
Urban areas	64	6200	64	3040	64	3160
Rural and mountainous Areas	104	7677	104	3875	104	3802
Questionaire responses	168	273	168	273		
Classroom observations	336		168		168	
Interviews/ group discussions	20	80	40	80		

3.5. Intervention procedure

The experimental group in this study will receive mathematics instruction that incorporates the use of digital games and AR games as supplementary tools. The control group, on the other hand, will receive traditional instruction without the use of digital games or AR games. The intervention will be carried out for a specific duration, ensuring that both groups receive an equal amount of instructional time.

To support the implementation of the intervention, the research will utilize various digital learning materials and tools. These include the MathVN learning app and the FarmMathematics app, which are designed to enhance mathematics learning. In addition, a Learning Management System (LMS) will be provided to teachers and students, offering support and resources for efficient learning. These tools have been developed by The Vietnam National Institute of Educational Sciences and UNICEF Vietnam, aiming to improve the teaching and learning of mathematics.

The research methodology will adhere to a systematic approach. Initially, educators will partake in a comprehensive one-day training session, acquainting themselves with the Learning Management System (LMS) and mathematics applications designed for instructing primary school pupils. They will also receive explicit guidance on utilizing lesson plans that seamlessly integrate the LMS and Mathematics learning game app, in addition to administering the post-lesson evaluation. Subsequently,

teachers will adapt and customize the lesson plans according to their students' specific requirements, while benefiting from the advice and support of experts. The implementation of teaching plans will then take place within the classroom setting, encompassing both traditional instruction methods and the integration of digital and AR games. To gauge the efficacy of the interventions, the post-lesson evaluation will be conducted among students in both the experimental and control groups to assess their learning outcomes. Throughout the research process, teachers will conduct classroom observations encompassing both experimental and control groups. They will provide reports on their experiences and insights gained from implementing the experimental teaching methods. After conducting the lessons, questionnaires about the effectiveness of the implementation will be administered to teachers (168) and students (273 randomly selected students from the treatment group). Additionally, a subset of teachers (20) will participate in interviews, while students (80) will engage in group discussions to gather their perspectives on the intervention.

Data collection will include classroom observation sheets, student test results, teacher reports, and feedback from questionnaires and interviews. These data sources will provide valuable insights into the effectiveness and impact of incorporating digital games and AR games in mathematics education.

3.6. Data analysis

Quantitative data will be processed using the SPSS software to analyze the data in terms of quantity, frequency, mean values, and reliability. Statistical techniques of t-tests will be employed to compare the performance of the experimental and control groups based on the quantitative data from the post-lesson tests.

Qualitative data, on the other hand, will be analyzed using Nvivo 7 software to identify patterns, themes, and specific cases related to the impact assessment. Content analysis will be utilized to extract meaningful insights from the qualitative data collected during classroom observations, focusing on student engagement, interaction, and perceptions.

3.7. Ethical considerations

Prior to the commencement of the study, ethical approval will be sought from the relevant institutional review board or ethics committee. Informed consent will be obtained from all participants, including students and parents/guardians, ensuring their understanding of the study's purpose, procedures, and potential risks and benefits. The confidentiality and privacy of the participants will be strictly maintained throughout the study, with all data anonymized and stored securely.

4. Findings and discussion

4.1. Impacts on students' academic performance in mathematics.

The research findings revealed significant positive impacts of digital games and AR games on students' ability to acquire knowledge and mathematical concepts in mathematics education.

Table 2. Mathematics test results

Learning content	Group types	N	Grade 1	
			M	SD
Grade 1	Treatment	2856	8.07	0.654
	Control	2924	7.32	0.830
Grade 2	Treatment	4059	7.24	0.324
	Control	4038	6.89	0.211

Table 2 presents the mathematics test results for the different learning content types in both Grade 1 and Grade 2, comparing the treatment group and the control group. For Lesson 1, in Grade 1, the treatment group had a mean score of 8.07 with a standard deviation of 0.654, while the control group had a slightly lower mean score of 7.32 with a standard deviation of 0.830. In Grade 2, the treatment group achieved a mean score of 7.24 with a standard deviation of 0.324, compared to the control group with a mean score of 6.89 and a standard deviation of 0.211. These results indicate that students in the treatment group performed slightly better on the mathematics test compared to the control group in both Grade 1 and Grade 2. To determine the statistical significance of these differences, independent samples t-tests were conducted. The t-test results indicated that the difference in mean scores between the treatment and control groups for Grade 1 ($t = 1.68$, $p < 0.05$) and Grade 2 ($t = 1.92$, $p < 0.05$) was statistically significant. Overall, the data, along with the results of the t-tests, suggest that the integration of digital games and AR games in mathematics education may have contributed to improved performance in terms of mathematics test scores. These findings provide robust evidence supporting the positive impact of digital games and AR games on student performance in mathematics.

In addition, the data from both the teachers' and students' responses strongly indicate the effectiveness of digital and AR game applications in improving students' understanding of mathematics lessons. In the teachers' response, a majority of teachers (51.3%) agreed that using digital and AR games helps students understand the lessons better, with an additional 17.5% strongly agreeing with this statement. Only a small percentage (4%) disagreed with the effectiveness of these applications. The student's response also supports this finding, with a significant portion (53.1%) agreeing that using mathematics apps (AR and games) helps them understand the lessons better. Additionally, 24.5% of students strongly agreed with this statement, while 18.3% partially agreed. A small percentage (4%) disagreed with the effectiveness of these applications. The consistency between the teachers' and students' responses reinforces the notion that digital and AR game applications are indeed effective in improving students' understanding of mathematics lessons. Both teachers and students recognize the benefits of these tools in enhancing comprehension and facilitating learning.

Table 3. Teachers' and students' responses to the statement on the effectiveness of digital and AR game applications in enhancing understanding of lessons (%)

	Disagree	Partially Agree	Agree	Strongly Agree
Teachers	4	27.2	51.3	17.5
Students	4.0	18.3	53.1	24.5

Through classroom observations and interviews, many teachers and students emphasized the effectiveness of these technologies. One Grade 1 teacher commented, "*Using digital games and AR games in mathematics instruction has made a difference in my students' academic performance. The attractiveness and repetition of the games have helped them understand mathematical concepts more effectively*." A Grade 2 student shared their perspective, stating, "*I used to find mathematics difficult and boring, but when we started using digital games and AR games, it became so much fun! I was able to understand mathematics concepts. It has definitely improved my understanding of math*." Another Grade 1 teacher added, "*The games provided immediate feedback, which helped students identify and correct their mistakes right away*."

However, along with the positive impact, a few limitations or weaknesses were identified. One limitation highlighted by a teacher was the need for careful monitoring and guidance during the use of digital and AR games. They mentioned, "*Some students may require additional support to fully understand the mathematical concepts presented in the games*." Students also shared certain challenges that affect their learning outcomes. One student expressed, "*The instructions in the games are unclear, and I did not know how to play. As a result, it was difficult for me to understand the lesson*." Another limitation mentioned by a teacher was the potential for students to become overly focused on the game mechanics rather than the underlying mathematical principles. Furthermore, concerns were raised regarding the limited scope of mathematical topics covered in digital and AR games.

In general, the research results highlight both strengths and weaknesses in developing students' mathematical performance through the use of digital and AR games. By considering these two aspects, educators can harness the full potential of digital and AR games to enhance students' mathematical performance and foster a deeper understanding of mathematical concepts.

4.2. Impacts on students' skills development

The data from the teachers' and students' responses provide insights into how they assess the impact of digital and AR game applications on improving students' transferable skills. According to the teachers' responses, a significant majority (65.8%) agreed that using digital and AR games helps develop skills such as collaboration and communication. Additionally, 40.6% of teachers agreed that these applications enhance problem-solving and creativity skills, while 60.3% agreed that digital and AR games foster self-directed learning for students. The students' responses also support the teachers' assessments. A majority of students (55.7%) agreed that using mathematics apps helps them communicate, collaborate, and exchange ideas with their peers. Furthermore, 56.0% of students agreed that using AR and game-based

mathematics apps in class helps them be more proactive and engaged in completing group-assigned tasks. Together, these findings demonstrate the potential of digital and AR game applications to not only improve students' understanding of mathematics concepts but also cultivate essential transferable skills that are crucial for their overall development and success.

Table 4. Teachers' assessment of the effectiveness of digital and AR game applications in developing students' skills (%)

Teachers' response	Disagree	Partially Agree	Agree	Strongly Agree
Develops skills such as collaboration, communication	6	30.2	65.8	0
Enhances problem-solving and creativity skills	7	43.9	40.6	8.5
Fosters self-directed learning for students	5	20.2	60.3	14.5

Table 5. Students' assessment of the effectiveness of digital and AR game applications in developing students' skills (%)

Students' response	Disagree	Partially agree	Agree	Strongly agree
Using mathematics apps (AR and games) helps me communicate, collaborate, and effectively exchange ideas with my peers.	4.0	17.2	55.7	23.1
Using AR and game-based mathematics apps in class helps me be more proactive and engaged in completing assigned tasks.	3.3	15.0	56.0	25.6

The qualitative research results give more insights and details into the landscape of applying technology in teaching Mathematics. Based on the teachers' classroom observations, it is evident that students present many activities that help to develop different skills. In terms of collaboration and communication skills, in a collaborative task, students are required to work together to play and win, so they actively participate in discussions and articulate their ideas clearly. For instance, one teacher noted, "*During group work, I observed students actively listening to each other's ideas, sharing their thoughts, and working collaboratively to be able to win the game*."

When it comes to problem-solving and creativity skills, while some students excel in these areas, others demonstrate average or below-average proficiency. As the teacher explained, "*I observed that a few students demonstrated perseverance and critical thinking skills in finding alternative solutions. However, some students appeared impatient and wanted to quit the game*." In terms of self-directed learning, a significant proportion of students display average to good skills. They demonstrate a level of

independence in their learning. However, while a considerable number of students show proactive behavior and high levels of engagement in their tasks, there are others who exhibit below-average levels of proactivity and engagement.

These findings provide valuable insights for educators to tailor their instructional strategies and interventions to enhance students' skills and promote their overall growth and development. These examples illustrate the skills demonstrated by students during actual activities, highlighting their abilities in collaboration, problem-solving, and communication.

Through interviews conducted with teachers and students to evaluate the development of students' skills after the integration of digital and AR games, some weaknesses emerged. While the overall impact was positive, it is important to consider these aspects for further improvement and refinement. One limitation identified by a teacher was the potential for students to become overly reliant on digital and AR games for skill development. They noted, "*Some students may become dependent on the games, which may hinder their ability to transfer those skills to real-world contexts*." Students also expressed, "*Sometimes, I only pay attention to the digital devices and forget about my friends*."

Another limitation raised by a teacher was the need for varied instructional strategies to cater to different learning styles. Furthermore, concerns were voiced regarding the potential for limited opportunities to practice skills outside of the digital and AR game context and the addictive nature of digital games.

Acknowledging these pros and cons enables educators to address them effectively. By incorporating a balanced approach that combines the benefits of digital and AR games with other instructional methods, such as hands-on activities, real-world applications, and open-ended problem-solving tasks, students can further develop their skills in a comprehensive manner.

Additionally, providing opportunities for reflection and the transfer of skills from the game environment to authentic situations can help students bridge the gap between virtual and real-world contexts. By addressing these limitations, educators can optimize the potential of digital and AR games to enhance student's skill development and facilitate their application in various scenarios.

4.4. Impacts on students' interest and motivation in learning mathematics

The data collected from both the teachers' and students' responses offer valuable insights into the influence of digital and AR game applications on students' interest and motivation in mathematics.

According to the teachers' responses, a majority of teachers (75.8% and 9%) agreed and strongly agreed that using digital and AR games increases students' interest and motivation in learning math. Only a small percentage (2%) disagreed with the impact of these applications on students' interest and motivation. The responses from students further corroborate this finding. A significant number of students (48.7%) expressed their interest in mathematics through AR learning. Moreover, 28.2% of students strongly agreed with this statement. While some

students expressed partial agreement or slight disagreement, the overall response suggests a positive impact on students' interest and motivation. The alignment between the teachers' and students' responses highlights a consensus regarding the positive impact of digital and AR game applications on students' interest and motivation in mathematics. Both teachers and students recognize the ability of these tools to make learning mathematics more enjoyable and engaging.

Table 6. Teachers' and students' assessment of the effectiveness of digital and AR game applications in enhancing students' interest and motivation in learning Mathematics (%)

	Disagree	**Partially Agree**	**Agree**	**Strongly Agree**
Teachers	2	13.2	75.8	9.0
Students	4.0	19.0	48.7	28.2

Analyzing students' interest and motivation to learn mathematics implemented in digital and AR games through teachers' classroom observation reveals positive outcomes. During the classroom observations, it was evident that students' interest and motivation in learning mathematics were significantly heightened. Students actively participated in the mathematics activities, displaying an eagerness to participate in activities based on digital and AR game applications. Teachers noticed increased engagement in taking on math-related challenges. One teacher noted, *"I observed a notable shift in students' attitudes towards math. They were excited to interact with the digital and AR games.*" During the mathematics lessons, teachers observed a remarkable transformation in shy or weak mathematics performance students. These students, who previously struggled or lacked confidence in math, exhibited a noticeable improvement in their participation and performance. The digital and AR games created an immersive and stimulating learning environment, strongly confirming that they fostered active student involvement and empowered them to confidently articulate their mathematical concepts. One teacher observed that weak mathematics performance students began to grasp mathematical concepts more effectively through the interactive nature of the games. One Grade 1 teacher commented, "*Using digital games and AR games in mathematics instruction has made a difference in my students' academic performance. They have become more engaged in learning mathematics*."

Interviews with both teachers and students provided valuable insights into the impact of these technologies on students' engagement in learning math. During the interviews, teachers highlighted the significant increase in students' interest and motivation. One teacher expressed, "*I have noticed a remarkable shift in my student's attitude towards math. They are now more eager to learn and actively participate in mathematics lessons since we started incorporating digital and AR games. It has made mathematics more enjoyable and accessible to them*." Another teacher reported that a first-grade student in their class became deeply absorbed in the lesson and felt distressed when it ended, crying because they wanted to continue playing. Moreover, the students themselves shared their personal experiences and affirmed the positive impact of digital and augmented reality (AR) games on their interest

in math. One student specifically expressed, "In the past, I found mathematics to be dull and difficult. However, ever since we started using these games, it feels like playing, and I now enjoy solving mathematics problems." The interviews consistently revealed that the integration of digital and AR games has sparked a renewed sense of interest and motivation among students. The interactive and immersive nature of these technologies has transformed the learning experience, making mathematics more enjoyable, accessible, and relatable.

However, a few limitations or weaknesses were identified through interviews and group discussions with teachers and students. One limitation mentioned by a teacher was the potential for over-reliance on digital and AR games. They expressed, "*Some students become so engrossed in the games that they may neglect other important aspects of learning, such as practicing problem-solving without the digital tools*." One student also remarked, "*Sometimes the technology can be distracting, I am so sad and lose learning motivation when the device is loss of internet connection and I can not play games*." Additionally, there were concerns raised about limited access to technology, especially for students who do not have access to devices or reliable internet connections at home. One student mentioned, "*I do not have a smartphone and internet at home, then I can not practice at home*." Another limitation raised by a teacher was the addictive nature of digital games. One student mentioned, "*When I have access to mobile phones or tablets, I want to explore more games, even ones that are not for learning Maths*."

Overall, the integration of digital and AR games in primary mathematics education offers significant potential for improving students' interest, motivation, and skills in mathematics. By leveraging the strengths and addressing the weaknesses, educators can create a dynamic and inclusive learning environment that promotes active participation, deep understanding, and enjoyment of mathematics among students.

5. Factors influencing the effectiveness of implementing digital and AR games in teaching primary school students

Gender factors

Data analysis from the study indicates significant factors that influence the effectiveness of using digital and AR games in mathematics education. In terms of gender, the research findings show no significant difference in the impact of using digital and AR games activities on the effectiveness of mathematics education.

Table 7. Comparison of gender differences in perceptions of using digital and AR games in mathematics education

Gender		Mean	Std. Deviation	Std. Error Mean
I am more interested in Mathematics through AR lessons	Female	2.99	.743	.066
	Male	3.03	.844	.070

Gender		Mean	Std. Deviation	Std. Error Mean
Using mathematics learning apps (AR and games) helps me understand lessons better	Female	2.98	.715	.064
	Male	2.98	.815	.067
Using mathematics learning apps (AR and games) helps me communicate and collaborate effectively and exchange ideas with my peers	Female	2.98	.693	.062
	Male	2.97	.802	.066
Using mathematics learning apps (AR and games) in class helps me be more proactive and engaged in completing the assigned tasks	Female	3.08	.627	.056
	Male	3.01	.815	.067
Using mathematics learning apps (AR and games) helps me study Mathematics better at home	Female	2.99	.639	.057
	Male	2.98	.806	.067

Table 8. Comparison of means and variances in perceptions of using digital and AR games in mathematics education through Independent Samples Test

Independent Samples Test										
F		Levene's Test for Equality of Variances		t-test for Equality of Means						
		Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		
								Lower	Upper	
I am more interested in Mathematics through AR lessons	Equal variances assumed	2.327	.128	-.362	271	.717	-.035	.097	-.226	.156
	Equal variances not assumed.			-.366	270.793	.715	-.035	.096	-.224	.154
Using mathematics learning apps (AR and games) helps me understand lessons better	Equal variances assumed	1.818	.179	.048	271	.961	.005	.094	-.180	.189
	Equal variances not assumed.			.049	270.838	.961	.005	.093	-.178	.187

Independent Samples Test										
F		Levene's Test for Equality of Variances		t-test for Equality of Means						
		Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		
								Lower	Upper	
Using mathematics learning apps (AR and games) helps me communicate and collaborate effectively and exchange ideas with my peers.	Equal variances assumed	2.471	.117	.124	271	.901	.011	.091	-.169	.191
	Equal variances not assumed.			.125	270.982	.900	.011	.090	-.167	.189
Using mathematics learning apps (AR and games) in class helps me be more proactive and engaged in completing the assigned tasks.	Equal variances assumed	3.976	.047	.814	271	.417	.073	.089	-.103	.248
	Equal variances not assumed.			.830	268.026	.407	.073	.087	-.100	.245
Using mathematics learning apps (AR and games) helps me study Mathematics better at home	Equal variances assumed	5.315	.022	.140	271	.889	.012	.089	-.163	.188
	Equal variances not assumed.			.142	269.380	.887	.012	.088	-.160	.185

Table 7 and Table 8 shows the mean scores and standard related to the effectiveness of learning mathematics through digital and AR games based on gender. A t-test was conducted to examine if there were any significant differences between males and females in their assessments. Looking at the mean scores, there were no substantial differences between males and females across the factors assessed. The mean scores for both genders were relatively close for each factor, indicating a similar perception of the effectiveness of learning mathematics through digital and AR games. The t-test results further support this finding, as none of the

p-values were statistically significant. This indicates that there were no significant differences between males and females in their assessments of the effectiveness of learning mathematics through digital and AR games for any of the factors measured.

The interviews conducted with teachers and the observations made in the classrooms shed light on the influence of gender on students' experiences with digital and AR games. The data revealed some noteworthy findings regarding gender differences. One teacher remarked, "*Initially, I believed that boys would be more engaged in these activities, but over time, girls also displayed a high level of interest. In my assessment, both boys and girls exhibit similar levels of interest and engagement in digital and AR game-based activities*." Moreover, during classroom observations, it was evident that girls demonstrated perseverance in the face of technical challenges, whereas boys maintained a competitive spirit during gameplay.

The interviews conducted with students yielded interesting insights into potential variations between boys and girls in their learning experiences. One male student stated, "*Girls like us really enjoy playing digital games. They play games and solve Mathematics problems very well*". Another student shared, "*In our class, both boys and girls actively participate and take turns in every game*." These findings suggest that, within this particular group of students, there were no noticeable discrepancies in the learning experiences between boys and girls. It emphasizes the importance of fostering an inclusive learning environment that encourages the full participation and academic growth of all students, irrespective of their gender.

Regional factors

The regional factor is also an important consideration when evaluating the effectiveness of implementing digital and AR games in mathematics education.

Table 9. Students' perceptions of digital and AR games in mathematics education by area

Area		Mean	Std. Deviation	Std. Error Mean
I am more interested in Mathematics through AR lessons	Rural	2.82	.882	.083
	Urban	3.14	.706	.056
Using mathematics learning apps (AR and games) helps me understand lessons better	Rural	2.75	.865	.082
	Urban	3.14	.651	.051
Using mathematics learning apps (AR and games) helps me communicate and collaborate effectively and exchange ideas with my peers	Rural	2.76	.830	.078
	Urban	3.13	.653	.051
Using mathematics learning apps (AR and games) in class helps me be more proactive and engaged in completing the assigned tasks	Rural	2.88	.803	.076
	Urban	3.15	.663	.052

Area		Mean	Std. Deviation	Std. Error Mean
Using mathematics learning apps (AR and games) helps me study Mathematics better at home	Rural	2.82	.808	.076
	Urban	3.10	.654	.052

Table 10. Students' perceptions of digital and AR games in mathematics education using independent samples T-Test

Independent Samples Test										
F		Levene's Test for Equality of Variances		t-test for Equality of Means						
		Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		
								Lower	Upper	
I am more interested in Mathematics through AR lessons	Equal variances assumed	3.833	.051	-3.336	271	.001	-.321	.096	-.511	-.132
	Equal variances not assumed			-3.207	203.796	.002	-.321	.100	-.519	-.124
Using mathematics learning apps (AR and games) helps me understand lessons better	Equal variances assumed	11.566	.001	-4.281	271	.000	-.393	.092	-.574	-.212
	Equal variances not assumed			-4.073	194.678	.000	-.393	.096	-.583	-.203
Using mathematics learning apps (AR and games) helps me communicate and collaborate effectively and exchange ideas with my peers	Equal variances assumed	8.447	.004	-4.131	271	.000	-.372	.090	-.549	-.194
	Equal variances not assumed			-3.960	201.297	.000	-.372	.094	-.557	-.187

Independent Samples Test										
F		Levene's Test for Equality of Variances		t-test for Equality of Means						
		Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		
								Lower	Upper	
Using mathematics learning apps (AR and games) in class helps me be more proactive and engaged in completing the assigned tasks	Equal variances assumed	.389	.533	-2.978	271	.003	-.265	.089	-.440	-.090
	Equal variances not assumed			-2.878	208.875	.004	-.265	.092	-.447	-.084
Using mathematics learning apps (AR and games) helps me study Mathematics better at home	Equal variances assumed	3.843	.051	-3.134	271	.002	-.278	.089	-.453	-.103
	Equal variances not assumed			-3.018	205.619	.003	-.278	.092	-.460	-.096

The data presented includes mean scores, standard deviations, and standard error of the mean related to the effectiveness of learning mathematics through digital and AR games based on urban and rural areas. Looking at the mean scores, there were notable differences between urban and rural areas in their assessments of the effectiveness of learning mathematics through digital and AR games. Overall, students in urban areas tended to have slightly higher mean scores compared to students in rural areas for each factor assessed, indicating a more positive perception of the effectiveness of these technologies in learning math. The t-test results further support this finding, as some of the p-values were statistically significant. For the factors of being more interested in mathematics through AR lessons, understanding lessons better, effective communication and collaboration, and studying mathematics better at home, there were significant differences between urban and rural areas. These findings suggest that students in urban areas may have a slightly more positive perception of the effectiveness of learning mathematics through digital and AR games compared to students in rural areas. This could be influenced by various factors such as access to technology, educational resources, and teaching methods.

Another important factor to consider is access to electronic devices and the internet. Research results indicate a statistically significant difference, showing that urban students who have access to electronics and the internet tend to achieve higher effectiveness in their learning compared to rural students who lack such access. The survey results reveal that approximately 40% of students, particularly in rural areas, face inadequate conditions regarding equipment and internet connectivity for their learning needs. In these situations, students often rely on sharing devices with friends or participating in classroom activities to access the required apps.

The teachers' interviews and classroom observations gave more evidence of the factors influenced by different areas in the learning environment. One teacher stated, "*Students from rural areas often face challenges related to limited access to resources and technology, which can impact their learning experiences.*" This observation highlights the disparities in educational infrastructure and resources between rural and urban settings. Students from urban areas may have more access to a variety of educational experiences outside of the classroom. Additionally, during classroom observations, it was noticeable that students from rural areas showed resilience and adaptability in their learning approach, often making the most of limited resources. On the other hand, students from urban areas demonstrated higher levels of confidence and participation in classroom discussions and activities. These findings suggest that the differences in areas, such as access to resources, can shape the learning experiences of students. Teachers can consider these variations to create inclusive learning environments that cater to the unique needs and opportunities of students in different areas.

Table 11. Students' perceptions of their digital skills in using digital and AR games in mathematics learning by area

		Mean	**Std. Deviation**	**Std. Error Mean**
I can quickly set up/ install the app on my device.	Rural	2.80	.858	.081
	Urban	2.98	.724	.057
I am proficient in using the app's features	Rural	2.64	.815	.077
	Urban	3.01	.689	.054

For the factor "I can quickly set up/install the app on my device," the mean ratings for rural areas are 2.80, for urban areas are 2.98, with a standard deviation of 0.724 and a standard error mean of 0.057. The difference in means suggests that urban participants (mean = 3.01) are more proficient in using the app's features compared to rural participants (mean = 2.64). This difference is statistically significant ($p < 0.05$), indicating that there is a significant disparity in proficiency between rural and urban participants.

The teachers' interviews and classroom observations provided valuable insights into students' digital skills and their impact on the learning environment. One teacher mentioned, "I have noticed that students with strong digital skills are more confident and independent in using technology for their learning." This observation suggests that students who possess proficient digital skills are better equipped to navigate and utilize technology effectively. During classroom observations, it was evident that students with advanced digital skills demonstrated higher levels of engagement and efficiency when using educational applications and online resources.

Students' digital skills factors

The interviews and classroom observations conducted with teachers yielded significant findings regarding students' digital competencies and their influence on the learning environment. One teacher's remark, "*It is apparent that contemporary students possess adeptness in digital skills, demonstrating proficiency in navigating diverse digital tools and platforms*," emphasizes the students' aptitude for utilizing technology for educational purposes. Another teacher's observation, "*I have noticed that students with stronger digital skills exhibit higher levels of engagement and participation in online learning activities*," indicates a positive association between digital skills and student engagement. Furthermore, during classroom observations, it was noticeable that students with advanced digital skills demonstrated greater adaptability in using educational apps and online resources. These findings indicate that students' digital skills play a significant role in their learning experiences, enabling them to effectively utilize digital tools for educational purposes. Teachers can leverage these insights to design instructional strategies that incorporate digital technologies, fostering a more engaging and interactive learning environment for all students.

The interviews conducted with students of different levels of digital skills provided valuable insights into the variations in their learning experiences. One student with advanced digital skills stated, "*Having strong digital skills allows me to explore a wide range of online resources and platforms. It helps me to access and comprehend information more efficiently.*" This comment highlights the advantages of having advanced digital skills, such as enhanced access to resources and improved information processing abilities. In contrast, a student with limited digital skills expressed, "*I sometimes struggle to navigate online platforms and find relevant information. It can be overwhelming and slows down my learning process*." This statement underscores the challenges faced by students with limited digital skills in adapting to online learning environments. The interviews revealed that students with advanced digital skills demonstrated higher levels of engagement and self-directed learning, while those with limited skills faced hurdles in accessing and utilizing digital resources. These findings emphasize the importance of equipping all students with digital literacy skills to ensure equal opportunities for learning and success in the digital age.

The interviews conducted with students of varying levels of digital skills provided

interesting insights into the differences in their learning experiences. One student with advanced digital skills stated, "*I find it easier to access information online and use digital tools to enhance my learning. It allows me to explore topics more extensively and collaborate with others digitally*." This comment highlights the advantages of having strong digital skills, such as improved access to information and enhanced collaboration opportunities. In contrast, a student with limited digital skills shared, "*I sometimes struggle to navigate online platforms and find it challenging to complete digital assignments*." This statement indicates the difficulties faced by students with limited digital skills when it comes to engaging with digital learning resources. These findings suggest that students with higher digital skills may have an advantage in terms of accessing and utilizing digital tools for their learning, while those with lower digital skills may face challenges and require additional support. It emphasizes the importance of providing equitable access to digital resources and offering targeted support to students with varying levels of digital proficiency.

6. Discussion

The research findings revealed significant positive impacts of digital games and AR games on students' ability to acquire knowledge and mathematical concepts in mathematics education. The study agrees with previous research conducted by Klopfer et al. (2009), Chin et al. (2019), and Hwang et al. (2016), which also emphasized the effectiveness of using digital and AR games in mathematics instruction. The high percentage of agreement and strong agreement in the teachers' and students' responses further support the notion that digital and AR game applications are indeed effective in improving students' understanding of mathematics lessons (Russo et al., 2019). This research provides further evidence and confirmation of the practical value of applying AR games in teaching Mathematics.

The research also indicated the positive role of technology applications in enhancing students' skills. Overall, positive evaluations from teachers and students regarding the organization of digital and AR game activities suggest the development of collaborative, communicative, problem-solving, and self-learning skills. These findings are consistent with previous studies conducted by Romero et al. (2015), Hoffman et al. (2021), and Gecu-Parmaksiz and Delialioğlu (2020) on the impact of technology on students' skills. However, since the findings mainly rely on self-assessment by teachers and students, a more detailed measurement of skill development through the mathematics teaching process is needed. Further research on skill enhancement should be encouraged in the future (Gargrish et al., 2022).

Regarding enhancing students' interest and motivation in mathematics, the research findings also revealed a positive correlation. Numerous studies have indicated that students are highly enthusiastic about mathematics lessons when digital and AR games are involved. The quantitative data combined with qualitative research findings further elucidated and reinforced the discoveries of Nguyen et al. (2019) and Khan et al. (2017). Similarly, Hoffman et al. (2021) supported the positive impact on students' interest and motivation.

However, alongside the positive aspects of integrating digital and AR games

in primary school mathematics education, the research findings also identified limitations from the evaluations of teachers and students regarding technology integration in teaching mathematics. These limitations include excessive focus on gaming, the potential for addiction to electronic devices and games, and the lack of interaction and transformation skills in certain cases. This research complements previous studies that have highlighted limitations in game-based learning, as mentioned in the research by Carr (2012), Kebritchi et al. (2010), and Kwon et al. (2016). These findings provide insights and guidance for educators and policymakers in the effective application of technology in education.

Factors influencing the effectiveness of implementing digital and AR games in teaching primary school students were also evaluated in this research. The study examined factors such as gender, geographical location, device availability, and information technology proficiency to understand the influencing factors of technology integration in teaching. Regarding gender, the results indicated that there were no significant differences in the impact of digital and AR games on student performance between male and female students. This finding contrasts with the research conducted by Hoffman and Nadelson (2010), Khan et al. (2017), and Nguyen et al. (2019), which suggested that gender significantly influences students' access to technology and academic achievement. This study aligns with a few studies that indicated similar levels of interest, engagement, and understanding of mathematics lessons between both genders through the use of these applications. The findings of the study indicate gender equality in terms of access to and the effectiveness of digital and AR games in teaching Mathematics.

Furthermore, the study explored the influence of geographical factors by comparing urban and rural areas. The findings revealed that students from both urban and rural areas benefited from the use of digital and AR games in mathematics education, with slightly higher effectiveness observed for urban students. This difference may be attributed to the limited access to technology, devices, and information technology proficiency in rural areas, resulting in lower effectiveness. The research highlighted a significant regional disparity. This research complements studies on regional influencing factors. The research provides recommendations for policymakers and educators to enhance support measures and reduce regional disparities to improve educational effectiveness.

In conclusion, this research contributes additional proposals to the effective application of technology in teaching, specifically in the integration of digital games and AR games in primary school mathematics instruction. These recommendations supplement those proposed by previous researchers such as Timotheou et al. (2022) and Hoffman et al. (2021).

7. Conclusions and recommendations

In conclusion, this research study has shed light on the impact and effectiveness of incorporating digital and AR games in mathematics education for primary school students. The findings indicate that the use of digital and AR games has positive effects on students' performance, skill development, engagement, and motivation

in mathematics. Additionally, the study identified several factors that influence the effectiveness of implementing digital and AR games in teaching mathematics, including geographical factors, infrastructure conditions, and the level of technological proficiency.

Based on the research findings, several recommendations can be made to enhance the implementation of digital and AR games in mathematics education. Drawing from the research findings, a number of robust recommendations can be proposed to optimize the integration of digital and AR games in the realm of mathematics education. Foremost, diligent focus should be directed towards allocating resources and providing assistance to educators and students situated in underserved regions. Notably, the utilization of technologically advanced games, including AR games, necessitates access to fast internet connectivity and cutting-edge electronic devices, thus warranting substantial investment and support. These limitations have hindered accessibility and the effectiveness of educational technology applications in teaching. Therefore, it is crucial to address the needs of students in underserved areas. Secondly, enhancing the technological proficiency of teachers and students is essential to fully exploit the potential of educational technology applications. Teacher training programs should be strengthened to enhance their technological competencies and their ability to adapt to the diverse learning styles and preferences of students. Additionally, game-based activities should be designed to cater to the individual differences of students. Lastly, there is a need for further research on game-based educational technology applications for secondary school students to enhance accessibility and improve the effectiveness of secondary education.

The limitations of this research should also be acknowledged. Firstly, the study was conducted as a quasi-experiment with unequal sample sizes, and the experimental duration was relatively short, which may limit the in-depth evaluation of long-term effectiveness. Furthermore, the results of this study primarily relied on self-assessment from teachers and students, which may introduce subjectivity and biases in the evaluation process. To address these limitations, future research should focus on long-term experiments with more objective evaluation measures. Additionally, further investigation is needed to examine the effectiveness of digital and AR games in mathematics education for students in higher grade levels.

Even with its limitations, this research offers crucial perspectives on the potential advantages and obstacles associated with integrating digital and AR games into mathematics education. By taking into account the recommendations and addressing these limitations, educators and policymakers have the opportunity to make well-informed choices and establish dynamic and impactful learning settings that foster students' mathematical proficiency and success.

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