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Investigating the Role of Digital Game Applications in Enhancing Mathematical Thinking Skills in Primary School Mathematics Students

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ABSTRACT

Digital gamification develops critical thinking skills through engaging students in problem-solving via interactive learnings and challenging tasks. Therefore, the study aimed to investigate the role of game applications in the mathematical thinking skills of Jordan primary school students. Data was collected from 162 mathematics primary school students through the purposive sampling technique. Both pre-test and post-test analyses were conducted for both of control and experimental groups. The results in the analysis of covariance (ANCOVA) showed a statistically significance difference in the use of digital game applications over the traditional methods. Furthermore, gender differences were also shown statistically difference but this impact was very limited with male students outperforming female students in the post-test. However, no significant interaction effects were found between the teaching methods and gender. This study with its significant findings contributes to the fields of educational technology and mathematics education by demonstrating the effectiveness of digital game applications in improving mathematical thinking skills. It highlights the potential of these applications to not only enhance computational skills but also to promote critical thinking and problem-solving in mathematics. Moreover, the research emphasized the importance of integrating digital tools into curricula to support various learning styles and needs. The findings also raise important questions regarding gender-based learning differences which is setting the stage for future research that explores learning strategies to address these disparities.

1. Introduction

In the current technological revolution, scientific critical thinking plays an integral role among students, enhancing their social interaction, personal development, and professional growth [21].

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Historically, it also increases the individual's ability to process the information with their concept buildings and analyze it systematically and scientifically [2]. In a general perspective, scientific thinking is defined as an organized mental process aimed at understanding phenomena through collecting, analyzing, and interpreting evidence which is eventually drawing conclusions based on the scientific method [24]. Specifically, in the education sector, scientific thinking skills are essential in preparing students to keep bound with technological advancements and meet the evolving demands of the labor market [48]. This is the reason, Essien et al. [16] conducted study and emphasized that skills enable individuals to solve problems methodically through applying observation, experimentation, and analysis . Therefore, critical thinking becomes an integral area of research in the extant literature.

However, there were several areas in scientific critical thinking that included critical thinking, creativity and logic [15] but mathematics is an important filed. Historically, critical thinking in mathematics subject focused on evaluating and analyzing data to make rational decisions. Creative thinking in mathematics, increases innovative and unconventional problem solving which enhances the ability to understand relationships between ideas [14]. Critical thinking helps to deal with complex and abstract thoughts. Of these, mathematical reasoning is particularly important because it combines logical and analytical thinking. Mathematical thinking is based on reasoning which are aligned in formal logical rules, which help students to solve problems in a systematic manner [29] With the significance of critical thinking, in recent years, there has been a remarkable shift in the priorities of learning from memorization to the development of mathematical reasoning. These changes encourage students to understand concepts more deeply and meaningfully [3]. The goal is to develop critical thinking and creativity and to empower students to effectively solve mathematical problems. Two main approaches have been taken to achieve this: first, directly teaching conceptual skills through instructional programs that encourage students to develop new concepts based on their existing knowledge, and second, mathematical theory will be integrated into classes, making it an integral part of academic content. This approach helps students relate mathematical concepts to everyday experiences and develop a deeper understanding [3]. These studies enforced that critical thinking in mathematics subject is an important area of concern which increases the importance of this this study research.

The existing literature argued that digital game learning represents an innovative tool for integrating learning and entertainment [35]. These games provide an interactive platform that helps students in developing meaningful analytical thinking in a safe environment where they can experiment with problem-solving strategies [41]. Darmayanti [13] showed that digital games not only help increase motivation but also improve learning outcomes, as a result, and mathematical reasoning skills. Ishak et al. [20] also emphasized the positive impact of digital games in an engaging learning environment. Specifically, Chen and Chuang [8] further found that digital games increased student engagement and contributed to academic achievement through multimedia. Such games provided strong learning experiences which help to the students in engagement of contents. In a general perspective, Chen et al. [10] also further explained that digital games incorporate audiovisual elements help students understand complex mathematical concepts. Their research also further shown that digital games also increases the various learning styles which facilitate to the students in increasing the student critical skills mathematical knowledge. Baßeng and Budke [5] further explained that learning games should be developed with internal educational objectives clear, ensuring that they present ideas in the context of research and motivation. Further empirical study highlighted the role of digital games in increasing the critical thinking in learning STEM education. In addition, Najah et al. [30] also examined the role of digital games in advanced learning in STEM (science, technology, engineering and mathematics) subjects. Tang [47] also found that

gameplay enhances creative science problem-solving skills, providing a more active and engaging learning experience compared to traditional methods. These studies emphasized that digital gamification is an important for increasing critical thinking skills in mathematics. Therefore, study focused on the impact of gamification on students critical learning skills.

Despite these positive findings, many research gaps remain. Firstly, extant studies have been conducted on benefits of critical thinking on academic performance [11; 12; 26; 31]. While these studies have limited attention on benefits of the digital games in creating the mathematical critical thinking. This study contributed to fill this gap to test how digitalization could increase the critical thinking of individuals. Secondly, prior researchers have been accompanied on university level students or college-level students while having limited attention on primary school students [24; 25; 42; 47; 48]. Therefore, this study contributed to adding the literature in the context of Primary education. Thirdly, extant studies have been conducted on qualitative research study, while having limited attention to quantitative study [22; 38; 49]. Therefore, this study contributed literature in the context of quantitative study. Fourthly, research has not adequately addressed the impact of instructional methods, gender, and other contextual factors on digital game effectiveness [25; 48]. These areas require further research, as understanding the specific effects of digital learning games on primary mathematics may lead to more effective and targeted learning strategies. Lastly, prior literature also focused on other countries with limited attention to Jordan's primary education students. Therefore, this study contributed to testing the study's impact in the context of Jordan. After fulfilling these gaps, the study objective is to test the research that investigates the role of digital game applications in enhancing mathematical thinking skills in primary school mathematics students.

To achieve the aim of the study, three questions were raised as follows:

1) Are there statistically significant differences at the ($p \leq 0.05$) level in the acquisition of mathematical thinking skills among third-grade students due to the teaching method (digital games applications vs. traditional methods)?
2) Are there statistically significant differences at the ($p \leq 0.05$) level in the acquisition of mathematical thinking skills among students due to gender (male vs. female)?
3) Are there statistically significant differences at the ($p \leq 0.05$) level in the acquisition of mathematical thinking skills among students due to the interaction between teaching method (digital games applications vs. traditional methods) and gender (male vs. female)?

The rest of the paper is divided into four chapters, literature where discussed study from both theoretical and empirical perspectives. Further, research methodology also has been conducted where research design, survey methods and sampling techniques are discussed. Then data analysis and results will be conducted in the next section. Lastly, discussion and limitations have been discussed.

2. Literature Review

Games have received a great deal of attention in education due to their ability to transform traditional learning into more engaging and interactive experiences [48]. When combined with elements such as points, badges, leaderboards, and feedback loops, gamification creates an environment that encourages students to actively participate in their learning process [49]. Generally, active students participation is an integral for increasing the critical thinking skills through increasing the memorization [25]. When the students motivation increased through memorizations, then students critical thinking increased that leads in understanding of the critical content [47]. In contrast to traditional method, digital games increase the learning environment through providing ongoing stimulation that increase the critical thinking of student more effectively

[48]. These challenges require students to think critically as they consider strategies, make decisions, and solve problems. Instant feedback in gamified systems also plays an important role in this process. It enables students to quickly see the consequences of their actions, learn from mistakes, and modify their strategies accordingly, which is a key feature osf critical thinking [37]. This iterative process of trial and error, reflection and adjustment helps students develop a growth mindset, encouraging them to embrace challenges and see failure as a learning opportunity [40]. These studies emphasized that digital games are integral component to increase the students critical thinking skills.

Various empirical studies have been conducted on the impact of gamification on critical thinking skills. For instance, Heliawati et al. [18] conducted study on impact of gamification on critical thinking skills. They found that critical thinking is an integral factor to significantly enhance the critical thinking skills Suryani et al. [46] further investigated study on the impact of games on critical thinking during the academic year. Their study found that students who participate in game-based learning activities demonstrate significant improvements in critical thinking skills compared to traditional classrooms. The study revealed that interactive and immersive nature of games is important for developing critical thinking skills. On the other hand, Mao et al. [28] also examined the impact of games on collaborative learning, and subsequently, its impact on critical thinking and results indicated that these activities reinforced critical thinking and enhanced teamwork and communication. The study also found that the social aspect of gaming creates a supportive environment in which students can learn from each other, further enhancing their critical thinking skills. Chang and Yeh [7] examined the use of games in STEM education, specifically through interactive design and problem-solving situations. Their study also argued that students which are participating in the game based learning have more effective critical thinking. They also theories provided a dynamic and engaging environment where students could apply theoretical skills to practical problems which increases their critical thinking. They also further argued that further research could be explained on other countries to increase the variation in the results and using other research methodology.

Other studies also conducted on the relationship of gaming and critical thinking skills. Kang and Recard [23] explored study on the impact of gaming on the critical thinking skills. Their research found that role-playing lessons increased student engagement and critical thinking skills. The researchers emphasized the importance of setting goals and tracking progress in gaming environments which increases their critical thinking skills. Abbassyakhrin et al. [1] also examined the motivational aspects of gamification and its impact on critical thinking. Their study found that combination of intrinsic and extrinsic stimuli in game-based learning environments significantly increased students' critical thinking abilities. They also noted that the sense of accomplishment and recognition provided by gaming re-motivated students to engage in critical thinking tasks, ultimately leading to better academic outcomes. In another study, Abbassyakhrin et al. [1] has been found that gamification increases the critical thinking skills of individuals. They also argued that further research could be explored in other countries to increase the scope of the study. In other study, it was also found that gamification has positive and significant influence on critical thinking [7]. They also explained that educational institutions should focused on game based learning especially in developing countries to increase the students critical thinking.

In another study, Supnoon and Chonchaiya [44] further authors suggested that gender can influence critical thinking due to inherent differences in cognition and intellect. Research has shown that men and women tend to use different cognitive strategies and learning styles, which can affect their approach to complex cognitive tasks e.g., men tend to use abstract reasoning and logical analysis world of mouth plays a role, which is an important element of critical thinking [36]. In

contrast, women tend to excel in narrative reasoning and are more inclined to take a collaborative and relational approach, which in turn can enhance critical thinking by fostering a range of perspectives and broader analysis [45]. These conceptual differences can lead to strengths and weaknesses in critical thinking between men and women. For example, men may perform better on tasks that require logical deduction and critical thinking, while excelling on tasks that involve communication, empathy, and holistic analysis Hearing this difference below can help teachers develop their teaching strategies to help foster critical thinking across genders [27].

Several other studies on gender and critical thinking relationship has been conducted. For instance, Lin and Wong [27] found that women tend to perform better than men in the evaluation of complex ideas, especially in areas that require verbal expression of reasoning and moral judgment [27]. This may be due to women having stronger communication skills and a tendency to engage more in reflective collaborative learning. Other research also suggested that men can benefit from more reflective projects if it involve logical thinking and problem-solving, especially in STEM subjects [9]. These findings highlight the need for a balanced approach to critical thinking, which recognizes and addresses the unique strengths and challenges faced by each gender. Sun and Liu [43] conducted a study where they revealed that gender qualification could affect critical thinking. These findings highlighted the importance of implementing inclusive educational practices to promote critical thinking among men and women. Atan et al. [4] further found no significant gender differences in critical thinking among college students, suggesting that men and women have similar abilities in critical thinking but other studies. These findings highlighted that although overall critical thinking ability may not differ significantly by gender, specific areas of critical thinking may reflect gender-based strengths of culture and education influenced by experiences. Further, the study of Irwan et al. [19] also found that men generally scored higher than women. Based on the previous, the following hypothesis is formulated below,

H1: There is a statistically significant difference in the acquisition of mathematical thinking skills among third-grade students due to the teaching method (digital games applications vs. traditional methods).

H2: There is a statistically significant difference in the acquisition of mathematical thinking skills among students due to gender (male vs. female).

H3: There is a statistically significant interaction between the teaching method (digital games applications vs. traditional methods) and gender (male vs. female) in the acquisition of mathematical thinking skills.

3. Method and Procedures

The study sample consisted of 160 students from 8 private schools in Amman, Jordan. These students were purposefully selected due to the cooperation of school administrators and teachers, ensuring that the selected schools had the necessary infrastructure and readiness to integrate digital games into the Learning process. The study sample was divided into two groups namely the control and experimental group. Each group consisted of 80 students. Among these groups experimental group was taught through using digital games and on the other hand, control group received traditional teaching methods. To maintain consistency in the classroom environment, each group was further divided into four sections, with each section containing between 20 to 21 students. The random assignment ensured that any observed differences between the groups could be attributed to the teaching method rather than external factors. Among the gender distribution, both groups consisted of almost equal distribution of gender with a minor difference. 42 students were male and 40 were female in the control group. On the other hand, 40 students were male and 40 students

were females in the experimental group. This balanced distribution of male and female students across both groups, with a total of 80 male students (48.8%) and 82 female students (51.2%) in the entire sample, ensures that gender does not confound the results. This allows for a more reliable analysis of the impact of digital games versus traditional teaching methods on mathematical thinking, with gender being a non-significant variable in the comparison.

3.1 Learning Materials

The Learning materials were divided into two main sections: the first aimed at teaching mathematical topics using traditional methods, while the second focused on using digital games to teach the same topics. The learning material for the traditional methods was chosen from the third-grade graduate students of mathematics for the second term. Selected topics in the subjects were measurement through geometry which consisted of measuring length, weight, area, volume, and geometric shapes such as polygons and triangles. In the traditional method, these topics were taught through direct explanation through the teacher and the solving of written exercises. On the other hand, for the digital game-based method, the same mathematical topics were presented through the use of educational game applications. Such kinds of games were designed by using Macromedia Flash" in collaboration with in-formation technology specialists to create an engaging and interactive learning environment. These games were designed to cover topics such as measuring length, area, volume, and geometric shapes which ensures students could engage with these concepts in a hands-on, motivating way which is followed by [39].

3.2 Teacher's Guide for Using Digital Game Applications

The teacher’s guide was designed to facilitate the integration of digital game applications into the teaching of geometry and measurement. The guide aimed to help teachers effectively incorporate interactive digital games into their lessons, fostering greater student interaction and participation. It provided a framework for teachers to enhance the learning environment, helping students grasp complex mathematical concepts engagingly and entertainingly. The Teacher's Guide provided a detailed framework for integrating digital game activities into geometry and measurement lessons, providing step-by-step instructions for choosing and using appropriate games. A detailed lesson plan outlines the structure of each lesson unit and time allocation for each unit. The instruction highlighted specific digital games designed to align with educational objectives, helping students understand geometric shapes through interactive tools. Emphasizing the importance of interactive and engaging learning, the mentor pointed out how these games can enhance students’ understanding and academic performance. Further, validity of the guidelines was also confirmed through expert evaluation and pilot testing of 24 third-grade students. Pilot testing results showed that games could effectively increase the student’s communications which increase their engagement, and significantly improve their mathematical reasoning skills which demonstrates the true effectiveness of the strategy for academic achievement developed. This process was followed by [34].

3.3 Mathematical Thinking Skills Test

For both traditional and digital games-based test evaluation, a comprehensive test was conducted for the assessment of learning interventions effectiveness in teaching measurement and geometry. The test consists of 12 open-ended questions designed to will assess student understanding of content and their ability to apply mathematical concepts. The test focused on basic mathematical concepts such as induction, deduction, problem-solving, representation using visual aids, and classification. It was administered as a posttest in both experimental (digital games) and

control (traditional methods) groups. Through the comparison of the test results across experiments, the researchers measured the impact of teaching strategies on students' mathematical reasoning and there to apply their concepts in their practical approach. This test process was followed by [34].

3.4 Pre-testing and Data collection procedures

To ensure content validity, the first version of the test was reviewed by 10 experts in computer applications, instructional technology, and mathematics instruction. Each item was evaluated against behavioral objectives derived from the learning materials met, and focused specifically on measurement geometry for primary mathematics students. Items that reached at least 95% agreement from the reviewers were retained, ambiguous or inconsistent items were removed, and additional items were added to increase content through using a test-retest approach 10 days apart and assessed a test reliability sample of 24 students. The Pearson correlation coefficient of 0.89 indicated high stability and stability. In addition, difficulty-discrimination indices were calculated, which showed a reasonable change in question difficulty and an effective differentiation between low-performing and high-performing students. This confirmed the validity and applicability of the test and made it suitable for educational research and practical applications. On the other hand, various discrimination indices were calculated for each item with results showing the range of 0.571 to 0.792 which indicates a suitable variation in the difficulty level of the questions. The discrimination index, which measures the ability of the test items to differentiate between high- and low-performing students was also calculated and showed that the questions were effective in distinguishing between different performance levels. These results show that the construct fulfills the requirements of the construct validity which is suitable for educational research and practical applications. Pre-testing and pilot testing process was also followed in the study of [6].

After developing and validating the study tools, the researchers proceeded with the study following a series of well-defined steps to ensure the systematic collection and analysis of data. The first step involved meeting with the school principals to obtain permission to conduct the research. Once permission was granted, the experimental and control groups were selected, and the teachers in both groups were informed about the aims of the study. They were provided with computer games to be used in the instructional process, which was essential for delivering the experimental intervention. Afterward, the pre-test was administered to both the experimental and control groups to gather baseline data on students' knowledge of the relevant mathematical concepts. The classroom teachers were trained on how to incorporate the computerized Learning games into their lesson plans. For the control group, traditional teaching methods were employed, while the experimental group was taught using the computerized games approach. After the instructional period, both groups took the post-test to assess any changes in their performance. To analyze the collected data, the observed means and standard deviations for the pre-and post-test scores were analyzed Covariance (ANCOVA) was conducted on the post-test scores.

4. Data Analysis and Results

4.1 Hypothesis Results

The study analysis was conducted from both pre-testing and pilot-testing processes. In Table 1 both the results of control and experimental group results are predicted. Male students in the control group showed an increase in mean scores at the pre-test from 13.437 to a mean post-test of 15.787, and the adjusted mean score was increased in both males and females. In the same vein, in females mean values increased by 13.140 to 13.437. The control group had a total pre-test score

of 15.519, which increased to 16.998 at the post-test, indicating a positive moderate effect. In contrast, the experimental group using computer games showed remarkable improvement. The mean score of male students increased from 11.04 to post-test to 21.72 which is 42.21, showing a significant improvement in their performance. Furthermore, female students also improved significantly, with scores increasing from 13.84 to 21.45 which is showing a significant change. Furthermore, the adjusted mean square also improved by 21.99. Overall mean pretest score was 13.45 and increased significantly to the post-test mean of 21.74. Table 1 predicted results show that there are noticeable differences between the observed means of the total post-test scores in mathematics, which result from variations in the levels of the teaching method.

Table 1
Means and Standard Deviations of Mathematics Test Scores by Study Variables

Group	Gender	Pre-Test		Post-Test			
		Observed Mean**	St.Dev	Observed Mean	St.Dev.	Adjusted Mean	Standard Error
Control Group	Male	13.437	5.32	15.787	4.22	16.678	0.70
	Female	13.140	5.94	17.897	4.23	16.77	0.55
	Overall	15.519	5.53	16.998	5.01	16.123	0.43
Experimental Group	Male	11.04	4.45	21.72	3.33	42.21	0.67
	Female	15.84	4.23	21.45	1.78	21.99	0.54
	Overall	13.45	4.44	21.74	2.72	21.97	0.42
Overall	Male	11.64	3.58	19.99	3.69	21.67	0.55
	Female	14.55	3.73	20.03	3.26	20.57	0.57

*The average is calculated from 25 degrees

Furthermore, for the assessment of the study's apparent differences, an analysis of covariance (ANCOVA) was performed on the adjusted means of the total post-test scores. The first question result indicated that the F-value for the group (teaching method) is 40.377 with a significance level of 0.010 which is statistically significant. This shows that there is a statistically significant difference in student achievement based on the teaching method. The differences between the control group (traditional method) and the experimental group (digital games) are clear, with students in the experimental group achieving much higher mean scores (21.97) compared to the control group (16.12). This result suggested that the use of digital games has a positive impact on students' mathematics performance compared to the traditional method. The second question results further show that there is a statistically significant difference between males and females, with an F-value for gender of 5.974 and a significance level of 0.012. This indicates that gender has a statistically significant effect on student achievement. The third question results show that the F-value for the interaction between the group and gender is 1.967 with a significance level of 0.183 that is significant. This means that the interaction between the teaching method and gender is not statistically significant. The above results are predicted in Table 2 below.

Table 2:
Results of the Analysis of Covariance for the Total Post-Test Scores in Mathematics by Study Variables

Source of Variation	Sum of Squares	Mean Squares	F Value	Sig.	Practical Sig.
Test	789.735	680.989	101.823*	0.000	61.9%
Group	384.134	384.149	40.377*	0.010	42.5%
Gender	39.995	45.193	5.974*	0.012	9.5%
Group * Gender	14.987	14.178	1.967	0.183	3.4%
Error	390.897	8.556			
Total	1291.023				

*Significance level ($p \leq 0.05$)

5. Discussion and Implications

This study explored the impact of teaching methods through digital game applications versus traditional methods on students' mathematical thinking skills, with a focus on gender and the interaction between gender and teaching methods. The objective of the study was tested through three research questions. The first research question result showed that digital applications in the game applications have statistical differences with the critical thinking skills of third-grade students in Jordan. The key findings of the study show that digital game applications are innovative learning tool that significantly enhances students' mathematical thinking skills. Historically, these findings show that students who learned their skills using digital game applications scored significantly higher compared to students who learned using traditional methods [33]. This may be due to several key differentiating factors in digital games and between traditional learning methods. First, digital games provide an interactive learning environment that actively engages students, enabling them to apply mathematical concepts through interaction with the game, thus improving their understanding of mathematical thinking. Second, digital games provide immediate reinforcement and repetition, helping students to improve their skills quickly and effectively. The results are supported with following study of [1; 17; 44] where they enforced that digital games provide a stimulating environment through internal and external competition which helps in leading to improved academic performance. In highlighting the significance of these findings, it is suggested that Jordan's education system should apply digitalization in their educational system because integration of digital games into the Jordanian education system could offer a stimulating environment which could help to increase the internal and external competition that could increase student engagement and leading to significant improvements in academic performance.

Further second question results also show that gender in both of male and female perspectives have statistical differences in critical thinking skills in mathematical questions. If the change was different in both male and female findings the change in increasing the mathematical skills are very limited. Historically, it has been observed that male students scored higher on average than females, which may reflect some differences in engagement with digital games. A possible reason for this result is that this discrepancy could be explained through several factors which consisted of males who might be more familiar with technology and digital games, which enhances their response to this Learning method. Another possible reason is that cultural and social differences may be influenced by how males interact with digital game applications, as games are sometimes perceived as an activity more oriented toward males. Another possible reason for these results is that females may prefer more collective or interactive learning methods, which could explain their lower achievement compared to males in this study. The results are supported by the findings of [32; 36], where they also found that the findings of both males and females could be different from statistical perspectives. Thus, the study results highlighted that gender differences could significantly influence the critical thinking skills of their mathematics which argues for the adoption of strong instructional strategies for addressing the study disparities. This implies that educators should consider gender-specific approaches to enhance critical thinking development in both male and female students that could increase their academic performance.

Further third question results showed that interaction had little effect on student achievement. In other words, gender did not have a significant impact on the effectiveness of digital game applications compared to traditional methods in improving student achievement. A possible reason for these results is that there were some differences in achievement between male and female students but digital games are more effective as compared to traditional method. These findings suggested that the modern teaching method using digital game applications provides a neutral learning environment that all students can benefit from, regardless of their gender. These results indicate that educational technology may be able to overcome gender differences that may arise in

some traditional teaching methods. The findings of this study emphasize the importance of using digital games as a Learning tool in classrooms, [40] which are aligned with the study which showed that digital game applications provide an interactive and motivating environment that helps students engage with the learning material in ways that make learning more enjoyable and effective. Seeking these studies' importance for digital technologies in the learning process, it is enforced that educational institutions should be focused on the use of these games that could contribute to enhancing academic achievement because students could continuously review and interact with the content that could improve their understanding and helping them apply mathematical concepts more effectively. These findings suggested that using digital game applications in education is not only a way to motivate students but also enhances their overall academic achievement.

This study with the findings significantly enhances the existing body of research through expanding the understanding of the role of digital games in increasing mathematical critical thinking, especially in primary school. While most of the extant literature focuses on students at the university or college level, this study shifts the focus to primary students which is emphasizing that digital games play an important role in enhancing critical thinking at the primary school level. The main contribution of this study is to identify statistically significant interactions of gender and group dynamics, which have not been adequately considered in previous research. Findings suggest that digital games do not have the same effect on all students and gender and woman and overall learning environment (individual vs. group) significantly influences critical thinking. This interaction between gender and team-based group learning suggests that boys and girls may respond differently to digital games depending on whether they work individually or collectively, and thus a new understanding has emerged of how specific contextual factors can determine digital game effectiveness-based learning. Through addressing this nexus, the study improves the theoretical framework surrounding digital games and critical thinking which highlights the complex ways in which gender, group dynamics, and learning tools pass it by to emphasize cognitive development in young learners. The study also contributed to helping other researchers conduct their research which could increase the scope of this research.

The practical implications of these findings are for educators and policymakers which aim to improve the use of digital games in primary education. Through emphasizing the significant impact of gender on critical thinking development, the study calls for a more nuanced approach to the use of digital games in the classroom. Educators should recognize gender differences in how students engage with digital games and consider adapting the use of these tools so that boys and girls can benefit equally. Furthermore, studies suggested that group dynamics play an important role in enhancing critical thinking. Collaborative learning environments, where students can communicate, discuss, and solve problems together can offer more benefits in raising critical thinking than individual games. These insights could lead to the development of more effective learning strategies that blend digital game activities with collaborative, team-based activities to stimulate intellectual engagement and deeper learning. Furthermore, study focused on primary education in Jordan which provides a useful framework for integrating digital games into early childhood education in the region, potentially changing how foundational mathematical skills are taught. Throuhj considering gender and group dynamics, educators and policymakers could design and ensure inclusive which is engaging, and effective educational experiences that could increase critical thinking for all students and the benefits of digital gaming which is accessible to all individuals.

6. Conclusion, Recommendations, Limitations, and Future Research Directions

The study aimed to investigate the role of game applications in the mathematical thinking skills of Jordan primary school students. Data was collected from 162 mathematics primary school

students through the purposive sampling technique. Both pre-test and post-test analyses were conducted for both of control and experimental groups. The results in the analysis of covariance (ANCOVA) showed a statistically significance difference in the use of digital game applications over the traditional methods. Furthermore, gender differences were also shown statistically difference but this impact was very limited with male students outperforming female students in the post-test. However, no significant interaction effects were found between the teaching methods and gender. This study with its significant findings contributes to the fields of educational technology and mathematics education by demonstrating the effectiveness of digital game applications in improving mathematical thinking skills. It highlights the potential of these applications to not only enhance computational skills but also to promote critical thinking and problem-solving in mathematics. Moreover, the research emphasized the importance of integrating digital tools into curricula to support various learning styles and needs. The findings also raise important questions regarding gender-based learning differences which is setting the stage for future research that explores Learning strategies to address these disparities.

The study results have various recommendations, Firstly, based on the study results, it is recommended that it is the need of the times, teachers should learn and incorporate digital game applications into their teaching strategies. These games have proven to increase student engagement and academic performance which is making learning more interactive. Teachers should consider incorporating game-based learning into their classrooms regularly to create an environment where students are motivated and actively engaged in the learning process. Secondly, as the students have various learning styles where teachers should adapt their instructional strategies to these differences. This could include offering a mix of learning activities, giving students a choice of sports, or balancing individual and group activities to better solicit male and female students. Thirdly, it is also recommended that schools invest in the necessary infrastructure and training to support the effective implementation of digital sport applications. Access to technological resources and professional development opportunities for teachers will ensure that they are prepared to effectively integrate these tools, enhancing the overall quality of education and creating more active learning environments.

Based on study findings, study has several limitations that could be addressed in future research.

Firstly, study sample was limited on city where data collected from students of Amman, the capital of Jordan which limited the generalizability of findings for other countries. Therefore, further research could be explored on other countries to increase the generalizability of the findings. Secondly, study used the single assessment tool. While this tool offered useful data, it may not fully capture the range of cognitive abilities or the depth of student engagement. Future studies could benefit from using more comprehensive assessments, including qualitative methods such as interviews or classroom observations, to gain a fuller understanding of the impact of game-based learning. Further, time duration of the intervention was limited which may have been too short to assess the long-term benefits of digital games in learning settings. Therefore, it is argued that future research could provide more strong evidence of the sustained impact of game-based learning. In addition, study limited on pre-test and post-test process while ignored the advance statistical techniques. Therefore, future research could be tested on other statistical techniques like Partial Least Square (SEM) to increase the reliability of the findings that could increase the scope of the study.

Decelerations

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