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Gamified Mobile Learning Apps and Their Impact on Critical Thinking Skills for Environmental Education in Primary Students

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Abstract: Gamified mobile learning applications are transforming primary education by actively engaging young learners in developing critical thinking, particularly within environmental education. With the Single National Curriculum (SNC) in Pakistan emphasising both critical thinking and environmental awareness, there is an urgent need for innovative educational tools that can address these competencies from the early grades. This study examines how gamified mobile learning apps themed on environmental science can help Pakistani elementary school students think more critically. A quasi-experimental design was used to assign 120 students to two groups: an experimental group that used gamified environmental education apps and a control group that received regular lessons. Standardised tools were used to assess critical thinking about climate, sustainability, and ecological problem-solving before and after an eight-week intervention. It was found that the critical thinking scores of the experimental group increased from 58.3 to 72.4, whereas those of the control group increased only from 59.1 to 63.9, a 24% decrease. Many teachers and students who were asked said that students who used apps, such as games, were better at handling problems and knew more about environmental issues. The results show that adding gamified digital tools for environmental education to Pakistan's primary school curriculum could significantly help students learn to think critically and understand climate change. To increase the use of gamified mobile learning in early education to help children explore the world and develop 21st-century thinking skills, the paper suggests changes to policies and teacher training.

Keywords: *Critical thinking, Environmental education, Gamified learning, Mobile applications, Primary education*

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1. Introduction

Technology is increasingly used in modern schools to help students learn, especially in the early years when they are still building basic skills and attitudes (Chang et al., 2019). Gamified mobile learning apps are one of the most exciting new ideas, as they combine play and digital engagement to keep people interested and help them learn more (Lee et al., 2016). The basic theory in this field suggests that video games and digital play spaces can create highly engaging learning environments, aid in problem-solving, and foster brain development, which can enhance both reading and writing, as well as critical thinking, in ways that traditional teaching often cannot (Gee, 2003). These tools are based on constructivist learning theory, which posits that learners make sense of concepts through real-world problems and situations (Piaget, 1972; Vygotsky, 1978). These methods are instrumental in environmental education because they encourage students to think critically, combine, and evaluate complex ecological issues (Chang et al., 2019). The UNESCO Tbilisi Declaration (1977) and other international agreements have long advocated for teaching methods that foster critical thinking and problem-solving to address environmental issues worldwide (Karama, 2016). Critical thinking means reasoning, examining facts, drawing conclusions, and considering other points of view, especially with new or difficult topics. The Delphi Report

(Facione, 1990) of the American Philosophical Association states that it involves analysis, evaluation, reasoning, and deduction. Students use these skills to understand and solve difficult environmental problems (Facione, 1990; Facione, 1992).

Environmental literacy is growing worldwide as people seek to equip the next generation with the facts and critical thinking skills needed to address climate change, manage resources, and live in ways that don't harm the environment (Evans et al., 2017; Chang et al., 2019). The research indicates that interactive, game-based methods not only motivate students but also enhance their critical thinking abilities and participation in environmental contexts (Arslan et al., 2011; Sousa & Rocha, 2019). thRecent research has also shown that mobile technology has made learning even more accessible by enabling study anywhere and at any time, as well as providing digital and game-based learning opportunities in resource-constrained settings (Traxler, 2009). Game-based learning settings mimic real-world situations, providing students with opportunities to practice making choices, consider the consequences, and develop cognitive abilities essential for becoming a responsible citizen (Taylor, 1985).

Researchers studying digital game-based learning (DGBL) have found that technology can help schools overcome challenges such as time and space constraints by providing students with more flexible and engaging learning experiences than they would in a regular classroom (Chang et al., 2019; Hsu & Wang, 2018). These settings work best at getting students to take responsibility for their actions and to think about their responsibilities as environmental stewards when they include real-life environmental problems, stories, and exercises (Taylor, 1985; Norman, 2014). Digital games also offer unique opportunities for formative evaluation and feedback, enabling instructors to observe how students' critical thinking and environmental awareness have evolved (Sousa & Rocha, 2019). Researchers have demonstrated that tailored digital experiences, particularly when combined with mobile devices and BYOD (Bring Your Own Device) initiatives, can help young learners think critically and reflectively (Kong & Song, 2014).

Many scholars have stressed the importance it critical thinking in today's schools. In 1941, Glaser was the first person to say that critical thinking meant being able to think critically about problems, do logical study, and use logical reasoning. Since then, research has expanded this definition to include reflection, self-regulation, and the evaluation of evidence and arguments (Facione, 1990; Dwyer et al., 2015). The Delphi Report from the American Philosophical Association states that inference, explanation, assessment, and interpretation abilities are essential components of critical thinking that students need to develop (Facione, 1990; Facione, 1992). These abilities are crucial for addressing complex, unclear, and controversial environmental problems that require more than just memorising facts (Chang et al., 2019, p. 776).

Environmental education is an effective way to help students develop both environmental literacy and critical thinking it encouraging them to consider real-world problems, compare different solutions, and examine the moral, scientific, and social aspects of sustainability (Karama, 2016; Ministry of Education, 2014). Narrative, modelling, discussion, and inquiry-based teaching have all been shown to get students more interested and help them think more deeply (Arslan et al., 2011; Lee et al., 2016). Games, in particular, use competition, teamwork, and difficulty to encourage people to be curious, keep going, and think things through (Norman, 2014; Sousa & Rocha, 2019). This view is supported by new studies in environmental education. It stresses the need to blend old and new learning approaches, such as hands-on and game-based methods, to help students learn to think critically and become more environmentally friendly (Wals & Dillon, 2013).

New changes in how mobile learning apps are made and how they are used have made it possible to teach young people about environmental problems in fun and useful ways (Hsu & Wang, 2018). These apps use visual stories, problem-based tasks, and rapid feedback to help children learn about the world while improving their thinking skills (Chang et al., 2019). Students who play games about the environment are better at understanding it, more likely to engage in activities that help the environment, and more likely to apply what they learn in real life (Arslan et al., 2011; Sousa & Rocha, 2019).

There are calls for critical thinking and environmental literacy to be taught in basic schools around the world, including in the US, but many problems remain to be addressed. It is especially true in developing countries like Pakistan, where there aren't many digital training tools and materials (Chang et al., 2019, p. 775). A recent poll in Pakistan, for example, found that more than 60% of basic schools lack access to digital learning tools, and more than 75% of teachers said they hadn't received sufficient training in using technology to teach. Pakistan's Single National Curriculum (SNC) emphasizes the importance it understanding the world and thinking critically. But most students still study the old-fashioned way, which means they just memorize rather than pay attention (Government of Pakistan, 2020). They might not learn to think more deeply or fully grasp the complexity of environmental concerns. There aren't many real-world studies examining how gamified mobile learning apps can help basic schools in Pakistan teach about the environment. This is a big problem for both policy and practice (Chang et al., 2019).

Teachers often struggle to use technology to help students learn because they haven't had sufficient training, can't access enough devices, or aren't sure how well gamified digital tools work in the classroom (Rahman et al., 2021; Sousa & Rocha, 2019). Big changes to the curriculum won't make a big difference in the classroom if there isn't clear evidence and good models for putting them into practice. Additionally, the diverse cultural, linguistic, and socioeconomic realities of Pakistani classrooms necessitate research in these specific settings to determine whether digital innovation can be effective in environmental education and what impact it will have (Chang et al., 2019).

This research tries to fill up these gaps by:

- To examine how gamified mobile learning apps, affect the growth of critical thinking abilities in elementary school environmental education in Pakistan.
- To the differences in what students learn when they use gamified environmental education applications compared to when they get regular lessons.
- To find out what teachers and students think and feel about using technology to learn about the world and solve problems in a critical way.

The study's purpose is to provide a comprehensive, fact-based look at how digital games can help young people in a developing country learn to think more critically and better understand the world. Using both quantitative and qualitative data from classroom activities, the project aims to provide teachers, curriculum developers, and policymakers with practical guidance on how to improve 21st-century skills through environmental education (Sousa & Rocha, 2019).

This study has important implications for educational policy, practice, and research, especially for countries seeking to update their lessons and courses for the 21st century. The study shows that gamified mobile learning can help students learn about the environment and develop critical thinking skills (Sousa & Rocha, 2019; Chang et al., 2019, p. 775). This directly supports curriculum designers, policymakers, and teachers who want to prepare students to be resilient and ready for the future. The results can help make digital resources and teacher professional development programs more relevant to the local culture and needs. This will help ensure that the goals of Pakistan's Single National Curriculum and other international standards, such as those set by UNESCO, are met in the classroom (Karama, 2016; Taylor, 1985).

Using game-based learning (GBL) in environmental education is a positive step forward that could change the way we teach and learn by turning passive models into active, collaborative research groups. This educational approach is important for students to learn so they can be ready to address tough sustainability problems in the real world (Arslan et al., 2011; Ministry of Education, 2014). The ideas for this study came from the UN's Sustainable Development Goals. They are particularly related to UNESCO's 2020 Goal 4.7, which emphasizes the importance of education for long-term growth and involves everyone around the world.

In addition, the study's findings are a key driver of efforts to improve both teacher professional development and subject change. The suggested changes place a strong emphasis on developing higher-order cognitive skills, such as creative problem-solving, critical thinking, and digital fluency, in the early stages of schooling (Rahman et al., 2021). This study fills in a big gap in the existing research by focusing on data from Pakistan. It also offers useful suggestions for strategically implementing digital innovations in the country's basic school systems. These changes may increase awareness of the environment and encourage greater community involvement, enabling individuals to better address the complex issues of the 21st century (Chang et al., 2019).

2. Relevant Literatures

Digital game-based learning (DGBL) has been a popular area of educational study over the past 20 years because it can encourage active learning and foster higher-order thinking skills. Researchers have consistently shown that different digital games can help keep students interested and motivated in school learning, especially in science and environmental education (Chang et al., 2019, p. 774). DDGBL theory follows the constructivist framework in learning and argues that learners are most likely to learn effectively when they are actively engaged in interactive situations that demand critical thinking, reflection, and problem-solving (Piaget, 1972; Vygotsky, 1978). Research across different educational contexts suggests that gaming allows students to confront problems and explore alternative solutions (Lee et al., 2016; Sousa & Rocha, 2019).

As eco-learning becomes increasingly important worldwide, various Digital Learning Tools and Games for environmental education have emerged to inspire students to learn creatively. The UNESCO Tbilisi Declaration (1977), which emphasized critical thinking and action-based approaches, constitutes the basis of environmental education; however, (Karama, 2016). Additional research by Arslan et al. (2011) indicates that game-based learning presents students with meaningful context and opportunity to link scientific concepts with real-life environmental situations: These techniques have established that students' knowledge of the environment, a positive attitude towards the environment, and ability to participate in action relating to the environment have increased.

Studies worldwide have demonstrated that DGBL enhances critical thinking. For example, Hsu and Wang (2018) found that embedding game-like elements and student-created questions into learning platforms promoted a higher level of algorithmic thinking, along with deeper cognitive engagement. Lee et al. (2016) found that similar effects of cooperative game-based tasks are reflected in students becoming more reciprocal and thinking at higher levels, particularly when they must evaluate complex content. Norman (2014) also suggested that using games in digital game design is motivational and provides users with active learning, stimulating them with a problem that can have multiple solutions.

Electronic games have been used in environmental education to demonstrate the complex systems and trade-offs involved in sustainability decisions. The earliest application was Taylor (1985), who used simulation-based learning in environmental education. He discovered that students who have these kinds of experiences are more likely to reflect on their thinking and other people’s perspectives. Some recent developments in game design have enabled the integration it environmental elements into storytelling games to foster learning through story creation and decision-making (Sousa &

Rocha, 2019). It is also believed that these strategies are most appropriate for primary school children, as interest and relevance are essential for long-term behaviour and attitude change (Chang et al., 2019, p. 774).

The main goal of the DGBL study remains to define and improve critical thinking. Glaser (1941) was the first to suggest that critical thinking involves identifying the issue, applying logic, and reflecting on it. The Delphi Report of the American Philosophical Association (Facione, 1990, 1992) provided a more detailed view and considered self-regulation, evaluation, interpretation, and inference. Dwyer et al. (2015) reflect that judgment has been stressed. "Critical thinking only happens when students work through challenging problems and have to address their assumptions about the world and how they know what they know," they wrote, as they learn interactively by questioning their assumptions and reflecting on how they come to conclusions.

There is proof that DGBL can help people learn more about the world. A study by Chang et al. (2019) found that environmental digital games can be a useful tool for encouraging elementary school students to learn about and think critically about the world. Arslan et al. (2011) argued that children can 'play for good' and 'play things even better', suggesting that educational games succeed in making kids want to do something for the world and in making them more conscious of how their activities affect others.

In 2024, the Ministry of Education in Taiwan recommended problem-solving and mandated critical thinking as core subjects. They knew that events with games were good for them. A similar trend has been observed in Asian countries as well, where people are increasingly interested in learning through computer games. Several intervention studies (Chang et al., 2019, pp. 774–776) have demonstrated that the use of DGBL in Taiwan and China has enabled pupils to learn more about the environment and think critically. In these situations, digital games enable students to think critically and work collaboratively to address environmental problems.

Recent studies have shown that a mobile learning application may support individual in promoting their environmental and critical thinking abilities as well. With smartphones and tablets in such widespread use, educational games can reach more people than ever before. This is true for individuals in developing countries (Hsu & Wang, 2018). Learning on the go is even easier on mobile platforms, where flexible learning is possible. Because they can be taken anywhere, they can be used not only to link learning activities with lived experience and local community issues (as when students use locally relevant environmental questions as the basis for their study), but also to bring real-world concerns into a situation.

There is mounting evidence of the association between DGBL and superior assessment outcomes. For example, Sousa and Rocha (2019) reported that students involved in games that offered leadership or decision-making opportunities developed transferable analytical problem-solving skills. Similarly, Facione (1990) and Dwyer et al. (2015) observed that organized game-based therapies resulted in meaningful improvement on standardized tests of critical thinking. Digital tools that are gamified have significant potential, but they need to be used carefully. Lee et al. (2016) and Arslan et al. (2011) also emphasized the importance it giving players clear goals, timely feedback, and opportunities to reflect on their performance in games. The management of the classroom and the classroom climate that Teachers create are also important for producing successful results, as students tend to learn more when they discuss what they did after game activities (Taylor, 1985; Norman, 2014).

The literature also discusses challenges related to accessing technology, preparing teachers, and ensuring alignment with curricular requirements, particularly in underdeveloped countries (Rahman et al., 2021). Not only do DGBL programs require good technology, but instructors also need to continue learning, and schools need to promote new ideas (Chang et al., 2019).

A body of work has shown that DGBL is good for critical thinking and environmental literacy, but this largely holds true in well-resourced countries with robust digital infrastructure (Chang et al., 2019, p. 776). However, there still aren't enough in-depth, context-sensitive studies of places like Pakistan, where classroom realities, teacher training, and access to technology vary drastically from those in richer countries. Additionally, the other studies that have compared groups on gain scores in critical thinking all took a much shorter view of learning outcomes. Earlier research concluded that it did not matter what type of classroom activities students engaged in for critical thinking skill development, or whether they only paid attention to changes in student behaviour over the short term. As Arslan et al. (2011) and Chang et al. (2019, p. 777) recommended, because game involvement interventions can be effective in improving attitudes and behaviors concerning the environment outside of school, long-term effects should be more thoroughly researched.

Also, much of the research focuses on DGBL as an elective class or as part of the extended curriculum, rather than the core curriculum (The Ministry of Education, 2014). It is harder to understand how game-based learning would become more commonplace and sustainable within formal education systems, particularly in countries like Pakistan that are experiencing major curricular shifts, e.g., the Single National Curriculum (Government of Pakistan 2020). Teachers' problems are another major divide. Although the benefits of DGBL are well-studied, there is less information on how teachers in underdeveloped countries perceive, implement, and put these strategies into practice (Rahman et al., 2021). There are still queries about Pakistani educators to acquire the training, support, and necessary resources for gamified applications that they can actually use in their classrooms.

Furthermore, there has been little research on the effectiveness of digital game-based tools for environmental awareness against traditional approaches in low- and middle-income settings. As a result, one of the constraints is that large-scale use of DGBL in Pakistan's environmental education to promote and foster temporary thinking is not supported by sufficient evidence, which means potential impacts are required for evidence-based policy. Last but not least, there have been only a

few informal studies examining how students and teachers use DGBL every day. So far, quantitative methods have been the most common. The subtle ways that digital games affect motivation, teamwork, and self-reflection on learning are still not fully understood (Chang et al., 2019).
The current work bridges this gap by examining how gamified mobile learning applications are used for environmental education in Pakistani primary schools, employing a multi-method approach. The study offers new evidence on the promise and challenges of using digital technology to improve critical thinking and environmental knowledge in developing countries by examining both learning outcomes and stakeholder perspectives while integrating the intervention into a core curriculum.

3. Materials and methods

Research Design

By adopting a quasi-experimental mixed-methods approach, this study rigorously examined the influence of gamified mobile learning apps on primary school students' critical thinking skills in environmental education in Pakistan. Quantitative and qualitative approaches would allow us to implement a cross-sectional study to develop an understanding of the outcomes measured and whether these experiences are experienced by intervention participants. The study design was based on best practices for educational intervention studies, which enabled a comparison of statistics and a deeper examination of the different perspectives of stakeholders (Chang et al., 2019, p. 776).
The research used a pre-test–post-test control group design, which is what it did. The participants were randomly assigned to one of two groups: the experimental group, which used gamified environmental education applications, or the control group, which continued learning in the same way they had always done in the classroom. To ensure reproducibility, randomization was performed using a computer-generated random number table. This resulted in an equal distribution of participants across the groups. Random assignment was used to reduce selection bias and increase internal validity. The qualitative interviews are there to frame the quantitative ones.

Data Collection

Data collection in the study occurred in two phases: quantitative analysis and qualitative interviews. The study sample comprised 120 primary school students selected from schools following the Single National Curriculum (SNC). To avoid misuse of statistical procedures and selection bias caused by not using purposive sampling, an equal number of students were randomly divided into two groups: the experimental group (n = 60) and the control group (n = 60). In the quantitative phase, standardized measures of critical thinking were used. These instruments measured essential competencies such as drawing inferences, interpreting, judging, and problem-solving in environmental contexts. The critical thinking standardised test consisted of sample questions like “Assess how deforestation affects the local environment” and “Offer suggestions on ways to decrease pollution in a city.” The test items were selected from reputable sources (Facione, 1992; Chang et al., 2019, p. 777) and had been slightly adapted to accommodate the local curriculum language and content.
Before the intervention, both groups took tests to establish baseline scores. The test group used mobile learning apps with environmental themes, which were turned into games, for eight weeks. These apps include live tests and real-time comments to help students learn about the world and think critically. Play-based apps are great for learning new things that are fun and useful. It's easy to get help, there are different levels of difficulty, and there are prizes for doing well. The people in the control group, on the other hand, kept reading books as an old-fashioned way to learn about the world.
After the intervention, both groups completed two assessments. In addition to standardized tests, semi-structured interviews were conducted with select students and their teachers from each group. The interviews explored participants’ attitudes toward learning, current problem-solving approaches, and views on environmental issues. All interviews were recorded and transcribed verbatim for analysis.

Data Analysis

The numeric data were analysed using statistical software, ensuring the review was fair and thorough. We used descriptive statistics to add up the two groups' demographic and baseline data. To see how scores changed between the experimental and control groups, we used independent-samples t-tests. The p-value was set to 0.05 or less because it was important. To better understand how the strategy worked, the study examined percentage changes in critical thinking outcomes. This made it easy to see how well the game-based approach helped students learn. We used Cohen's d to assess the practical relevance of the differences we observed where applicable.
Inductive theme analysis was conducted on the qualitative data. We coded the transcripts of the interviews to identify common themes, including critical thinking, problem-solving, involvement, and awareness of one's surroundings. The research team was able to double-check their results by having students and teachers talk about their own experiences. This gave the numeric data more depth of understanding. The approach used both strong quantitative methods and an in-depth

qualitative study to get a full picture of how gamified mobile learning affects the critical thinking skills of elementary school students in environmental education.

4. Results

4.1. Quantitative Findings

The study found that gamified mobile learning apps significantly improved elementary school students' critical thinking skills in environmental education. On the pre-test of critical thinking, the experimental group scored 58.3 (SD = 7.2), while the control group scored 59.1 (SD = 6.9). This means that there was no significant difference between the two groups at the start ($p > 0.05$).

The experimental group's average post-test score increased to 72.4 (SD = 6.3) after the eight-week intervention, representing a 24% improvement from the baseline. The control group, on the other hand, showed a slight increase in their average post-test score to 63.9 (SD = 7.1), representing an 8% improvement (see Table 1). An independent-sample t-test revealed that the experimental group experienced a significantly greater increase in critical thinking scores compared to the control group ($t(118) = 6.41$, $p < 0.001$). The effect size (Cohen's d = 1.02) indicated that the influence was substantial for learning.

Table 1: Mean Critical Thinking Scores (Pre- and Post-Test) by Group

Group	Pre-Test Mean (SD)	Post-Test Mean (SD)	% Change
Experimental	58.3 (7.2)	72.4 (6.3)	+24%
Control	59.1 (6.9)	63.9 (7.1)	+8%

Figure 1 illustrates these data on a graph, making it easy to see how the critical thinking scores of the two groups changed differently.

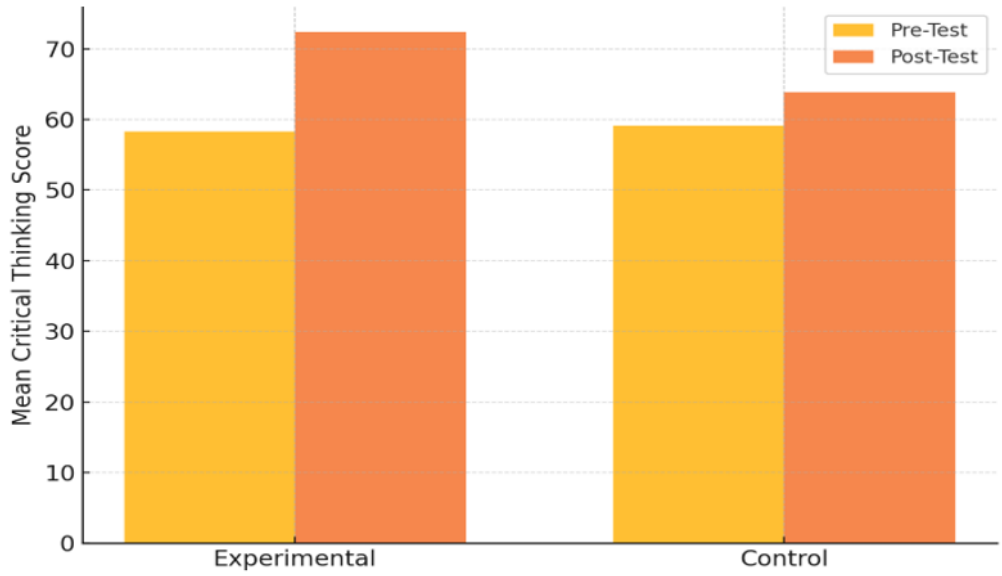

Figure 1: Comparison of Pre-Test and Post-Test Critical Thinking Scores

The usual critical thinking scores for both groups have increased over time, as shown in this bar chart. The experimental group, which used mobile apps designed to feel more like games, saw a much larger increase than the control group, which saw only a small increase.

4.2. Qualitative Findings

The numeric results were further supported by a qualitative study of interviews with students and teachers. Respondents in the test group said that apps that felt like games made environmental problems seem more real, which helped them understand them better. The data show the apps effectively taught users about environmental issues and their impacts. Many

of the respondents felt they had more control over their lives and were better prepared to handle new problems as they arose. I was told, "The games prompted me to critically reflect on my capacity for environmental stewardship and the root causes of pollution." Overall, these results demonstrate that the treatments moved people from passive knowledge to active, environmentally friendly behavior.

Teachers observed that students who utilised gamified learning apps employed reasoning, hypothesis testing, and reflective questioning more frequently during class discussions. “I noticed students asking more questions and trying to solve problems, not just memorizing facts,” shared a teacher, reinforcing the importance of problem-solving and critical thinking in the learning process. Several teachers noted that pupils were significantly better equipped to support their opinions with evidence from the situations in the apps. One teacher mentioned, “Students were able to explain their solutions using examples from the games, which they hadn’t done before when learning through textbooks.” This comment reflects an increase in evidence-based reasoning, a key component of critical thinking. On the other hand, students in the control group primarily relied on rote memory and showed less interest in participating in class. One teacher noted, “Students in the control group seemed disengaged, mainly repeating information from the textbook without trying to connect it to real-world scenarios.”

Table 2 shows some remarks from students and teachers that show common themes in the qualitative data.

Table 2: Representative Qualitative Comments from Participants

Participant Type	Example Comment
Student	"The games made me think about why pollution happens and what I can do to help the environment."
Teacher	"I noticed students asking more questions and trying to solve problems, not just memorizing facts."

These numbers show that using mobile apps that are like games to teach about the environment can make elementary school students think more deeply and become more interested. The experimental group did a lot better than the control group. This suggests that digital platforms made to look and feel like games might help improve more complex thinking. This shows that these tools should be used in basic school lessons.

4. Discussion

Interpretation

The results of this research indicate that gamified mobile learning apps can significantly enhance primary school pupils' critical thinking skills when learning about the environment. The study group's thinking skills increased by 24%, while only 8% of the control group improved. This shows how well digital platforms with games and other engaging elements can help build higher-order thinking skills. The results strongly back the study's main idea that technology-enhanced, scenario-based learning environments help students become more interested in learning, think more critically, and solve problems better. The qualitative data helps us better understand these results by showing that students who used gamified apps not only learnt more about environmental problems, but also became more eager to apply what they had learnt to solve real-world problems. This means that using gamified tools could be very important for raising the future generation of environmentally aware and skilled individuals in Pakistan.

Comparison with Previous Studies

These results are similar to those found by other researchers worldwide on the advantages of digital game-based learning for both cognitive and emotional development. Chang et al. (2019) found that digital games help elementary school students think more critically and learn more about their surroundings. This study backs up those results. The findings also align with those of Hsu and Wang (2018), who found that game mechanics and active inquiry facilitate critical and algorithmic thinking. Arslan et al. (2011) and Lee et al. (2016) also demonstrated that educational games encourage greater engagement, collaboration in problem-solving, and a desire to learn about the environment.

The study's numeric effect size, on the other hand, was much bigger than those seen in other treatments. Two key factors contributed to these positive results. First, we ensured that the learning applications aligned with the area program and classroom practices. Second, the eight-week period gave both teachers and students enough time to get used to the new way of doing things. The majority of previous studies in this area come from schools in high-income countries with substantial funding. Our study offers a useful perspective on issues from the perspective of a growing country. That it worked so well is especially interesting because it shows that new technology can have a big effect on learning, even in places with few digital tools.

However, the challenges people predicted would hinder adoption turned out to be quite different. Researchers have already found that teachers quickly learn and like new technologies when they are used in environments with abundant technology (Sousa & Rocha, 2019). But this study found that teachers were sceptical at first and had little experience with fun apps,

which made them hard to use. This issue has been examined in numerous studies from low- and middle-income countries (Rahman et al., 2021). This highlights the importance of teachers having professional development and ongoing support as digital technologies become increasingly prevalent in schools.

Limitations

Although the present research has some strengths, it also has certain limitations that need to be addressed. First, the quasi-experimental approach was good, but it didn't use random sample at the level of the institutions. Since this is the case, it might be harder to use the results in all Pakistani elementary schools. Second, the intervention time was longer than in many other studies, but it was still not long enough for behavior and attitude changes that might last. Third, the study used self-reported interview data and structured tests of critical thinking. These were useful, but they may not have fully captured the entire range of cognitive and emotional development or the subtle ways children apply critical thinking outside of school.

Additionally, differences in the level of excitement teachers displayed, the tools available in the classroom, and the amount of technology the children had previously used may have influenced the outcomes. Although the qualitative results were rich, they were based on a purposefully selected subsample and may not accurately represent all the diverse perspectives that exist among students and teachers.

Implications

Even with these problems, this study strongly supports the use of game-based digital tools for teaching about the environment, especially in developing countries like Pakistan. Lawmakers, lesson creators, and school officials can get ideas from it on how to use technology to help students learn about the world and think critically. To ensure that digital ideas remain alive and grow, the results also show that elementary schools need to keep training their teachers and providing technology support. To learn more about this important topic, we should use longitudinal methods and multi-site sampling and examine additional cognitive and social outcomes in future studies.

5. Conclusion

The goal of this research was to investigate the impact of gamified mobile learning apps on the development of critical thinking skills in environmental education among primary school children in Pakistan. The results show that incorporating digital game-based platforms into the curriculum significantly enhances students' critical thinking skills. The experimental group showed a significantly greater increase in critical thinking scores compared to the group that received traditional instruction. Qualitative data further supported these results. The qualitative data showed that all participants agreed that the gamified learning methods made students much more engaged, motivated, and adept at problem-solving. This was said by both students and educators. These results immediately fill the gap in local educational practice identified. They show that making learning more engaging with technology is an effective way to teach students about the world and help them think more deeply in early school settings.

Given these results, more research should explore a few other paths. We need longitudinal research to determine whether improvements in cognitive skills result in permanent changes in behaviour and active environmental citizenship and to assess whether advances in critical thinking are sustainable. Adding additional schools and areas to the sample would make the results more applicable to other situations and help determine the elements that affect performance in similar contexts. Further study should also examine models for the professional development of teachers and how to incorporate local environmental settings into gamified apps. Finally, mixed-methods studies that examine both cognitive and social-emotional outcomes would provide a better understanding of how digital innovation impacts learning in low-income countries.

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