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Effects of Video Games as Tool for Learning Science at Elementary Level

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Abstract

This study examined the effect of video games as an instructional tool for elementary school science students. The main objective was to determine how effective video games are as an instructional tool for students in elementary school. It was a quasi-experimental study. The sample comprised female elementary school girls enrolled in grade four in two public elementary schools. Were 39 students in the experimental group and 35 in the control group. The study's findings proved that the mean scores of students in the experimental group significantly improved when they received instruction through video games. This proved that video games are a more effective teaching and learning tool for science in elementary school.

Keywords: Video games, learning, quasi-experimental

Introduction

Science and technology education is vital in today's society, driving innovation essential for economic growth and global competitiveness. It creates employment opportunities, particularly in the rapidly growing STEM fields, and is crucial in advancing healthcare, environmental sustainability, and food security. This education fosters critical thinking, problem-solving, and informed decision-making, empowering individuals to contribute meaningfully to society. Moreover, countries prioritizing science and technology lead on the global stage, influencing international policies and promoting collaboration to address global challenges. Understanding science enriches our culture and raises important ethical questions, shaping the future of society

Unfortunately, science education in Pakistan has not much encouraging status. Weak science education is a significant issue that impacts the country's overall development and ability to

compete globally. Several factors contribute to weak science education in Pakistan.

There is a shortage of qualified and well-trained science teachers, especially in rural areas. Many teachers lack the necessary background in science subjects, which hinders their ability to teach effectively. Similarly, ongoing professional development opportunities for teachers are limited, leading to outdated teaching methods and a lack of innovation in the classroom. Many schools, particularly in rural areas, lack proper science laboratories and equipment, making engaging students in practical, hands-on learning experiences difficult. Outdated and poorly designed textbooks, along with a lack of supplementary teaching materials, further weaken the quality of science education (ASER, 2020; Nawab, & Shafi, 2021; UNICEF Pakistan, 2022; Shamim, & Rashid, 2023; GOP, 2023).

The science curriculum in Pakistan is often outdated, focusing more on rote memorization rather than critical thinking, problem-solving, and practical applications of scientific concepts. The curriculum does not always relate to real-world issues or the students' daily lives, making it less engaging and relevant to their needs (Nawab, & Ahmad, 2021).

The examination system in Pakistan heavily emphasizes rote memorization, with students focusing on memorizing facts rather than understanding concepts. This approach stifles creativity and critical thinking. Similarly, practical knowledge and scientific inquiry are not adequately assessed, leading to a focus on theoretical knowledge at the expense of practical skills (Ali, & Sheikh, 2022).

Government spending on education, particularly in science, is insufficient. This underfunding affects everything from teacher salaries to infrastructure development. Even when policies are in place to improve science education, there is often a lack of effective implementation and monitoring, leading to persistent gaps in the education system (Khan, & Bibi, 2021).

The Pakistani government has taken several initiatives to address issues related to science education, though challenges remain.

It has launched policies and education reform programs. National Education Policy 2017-2025 outlines goals for improving education quality, including enhancing science education. It emphasizes curriculum reform, teacher training, and infrastructure development. The policy is also aimed at promoting scientific research and technology development and also includes initiatives to improve science education (GOP, 2018).

The government, in collaboration with various organizations, has implemented training programs to improve the quality of science teachers. However, these programs are often criticized for being insufficient in addressing the scale of the problem. The HEC has launched programs to improve teacher education and provide professional development opportunities for educators (Siddiqui & Akhtar, 2022).

Some provincial governments have initiated projects to upgrade school infrastructure, including developing science laboratories and providing educational equipment. For example, the Sindh Education Sector Plan includes upgrading science facilities (Jafri, & Hassan, 2023).

Efforts have been made to revise and update the science curriculum to make it more relevant and engaging. The curriculum is being reviewed to focus more on critical thinking and problem-solving rather than rote memorization. Initiatives to develop and distribute new, more effective textbooks are ongoing, though progress is often slow (Ali, & Hussain, 2022).

The government has made efforts to increase funding for education, although critics argue

that allocations are still insufficient to comprehensively meet the needs of science education. Pakistan has received funding and support from international organizations, such as UNESCO and UNICEF, aimed at improving educational outcomes and infrastructure. Although malpractices are also reported (Khan & Zahid, 2023).

Various programs focus on promoting STEM (Science, Technology, Engineering, Mathematics) education, including national competitions and scholarships for students in these fields. Initiatives like the establishment of science and technology parks are aimed at fostering innovation and research, indirectly supporting science education (Ahmed, & Shahid, 2024).

Despite these efforts, challenges remain. There are often gaps between policy and practice, with inadequate implementation and monitoring of educational reforms. Improvements are often uneven, with rural areas and disadvantaged communities lagging behind urban centers in terms of educational resources and quality. While there have been increases in funding, it is still considered insufficient to address all the challenges effectively (Rashid, & Ahmed, 2023; Iqbal, & Khan, 2022; Farooq & Bano, 2021; Javed & Raza, 2020).

The current study is an effort to implement video games as a teaching tool for science subjects to fourth graders.

Research Objectives

The current study has the following objectives:

i. To ascertain how well elementary school students are currently learning science.

ii. To ascertain whether or not video games are a useful educational tool for elementary school pupils.

Review of Related Literature

Numerous studies have validated that the use of video games has facilitated the teaching-learning process. According to Okur & Aygenc (2017), video games are an effective learning tool that presents special chances for students of all ages to be engaged and educated. According to Connolly, Boyle, MacArthur, Hainey, & Boyle, (2012), well-made video games can greatly improve a variety of learning outcomes, such as motivation, problem-solving abilities, and knowledge acquisition. Similar to this, Wouters, Van Nimwegen, Van Oostendorp, & Van Der Spek, emphasized how video games' built-in features—such as interactivity, challenge, and instant feedback—can increase learning motivation and engagement (2013). The usefulness of video games in fostering inquiry-based learning in science education was highlighted by Li and Tsai (2013). They maintained that learning through video games gives students the chance to practice real-world scientific investigation, hypothesis testing, and data analysis. Video games can improve motivation, engagement, and learning results in science education. Game-based design concepts also help to maximize learning outcomes (Martinez, Gimenes, & Lambert, 2022). Furthermore, by offering dynamic, multimodal, and customized learning experiences, instructional video games can support cognitive processing, engagement, and learning (Mayer, 2017).

Studies have shown that after engaging in video games related to science, students' conceptual knowledge improved substantially (Putri, Rahayu, & Dasna, 2022; Qian & Clark, 2016; Foster, Koehler, & Mishra, 2006). According to Kaldarova, Omarov, Zhaidakbayeva,

Tursynbayev, Beissenova, Kurmanbayev, & Anarbayev, (2023) and Sung & Hwang (2013), the use of video games in the classroom increases motivation and knowledge while also fostering a positive attitude toward learning.

Due to their interactive nature, video games have emerged as a novel method for enhancing elementary science education (Houghton, Aston, Featherstone, Perrotta, Houghton, & Aston, 2013). They offer a stimulating approach that boosts student motivation, engagement, and information acquisition (Connolly et al., 2012; Papastergiou, 2009). They create realistic virtual environments for students to observe, experiment, and manipulate variables, which improves critical thinking and problem-solving skills (Vieira, Barros, Barros, Mendes, & Ribeiro, 2019).

Additionally, video games provide opportunities for social interaction and collaborative learning. Cooperative and multiplayer features help develop communication, problem-solving, and teamwork skills, essential for scientific research (Yang, Wen, & Yang, 2020; Khalid, Batool, Khalid, Saeed, & Zaidi, 2019). Recent studies support the benefits of using video games in science education. Vogel, Vogel, & Blume, (2021) found that instructional video games enhanced students' conceptual knowledge, while Li, You, Huang, and Fan (2022) observed improved academic performance and increased motivation in students using scientific video games.

As technology advances, integrating video games into science learning offers significant potential. However, ensuring that these educational games align with curriculum standards and learning objectives is important. Effective collaboration between game developers and educators is essential to create educational games that are both instructional and enjoyable (Zirawaga, Olusanya, & Maduku, 2017).

The aforementioned studies have highlighted the value of video games in teaching science to elementary school students. These games can significantly improve students' understanding of scientific concepts, motivation to learn, and interest in science instruction. Significant science learning objectives can be supported by incorporating educational video games into the elementary scientific curriculum.

Description of the video games used in the current study

The current study used three video games in the classroom for teaching science concepts to fourth graders.

i. Minecraft (https://education.minecraft.net/en-us)
ii. Toca boca Nature (https://tocaboca.com/)
iii. CBeebies Playtime (https://play.google.com/store/apps/details?id=uk.co.bbc.cbeebiesplaytimeisland&hl=en&pli=1

In the following lines, a brief description is given

i. Minecraft Education Edition

Minecraft was designed by a Swedish game developer Markus Persson, also known as "Notch". On May 17, 2009, the game was made available to the general public as a PC alpha. A full version was subsequently made available on November 18, 2011 (Persson, 2009). Minecraft education is a customized version of Minecraft created especially for use in educational settings. It is an effective tool for teaching and learning across a variety of

subjects since it has characteristics that support educational objectives (Mojang Studios, n. d.).

Here is a summary of the features and contents of Minecraft Education Edition:

a. **Classroom-Friendly Interface**:

Teachers can manage student accounts, assign roles, and control the in-game environment to suit educational needs. The platform provides a controlled environment where students can collaborate and interact without the risks associated with open online games.

b. **Educational Tools and Resources**:

Minecraft Education Edition comes with a library of lesson plans across subjects such as math, science, history, language arts, and more. These lessons are designed by educators and aligned with curriculum standards. It is a companion app that allows teachers to interact with students, monitor their progress, and manage the game world in real time. Teachers can use built-in tools to assess student work, provide feedback, and track learning outcomes.

c. **Collaboration and Communication**:

Students can work together on projects in a shared Minecraft world, promoting teamwork, communication, and collaborative problem-solving. The collaborative environment allows for immersive, hands-on learning experiences where students can experiment, explore, and create together.

d. **STEM and Coding Education**:

Minecraft Education Edition allows students to learn coding by interacting with in-game elements using block-based coding platforms like Tynker and Microsoft Make Code or text-based coding with Python. It also includes specific lessons focused on STEM subjects, enabling students to explore scientific concepts, engineering challenges, and mathematical problems within the game.

e. **Creative and Critical Thinking**:

The game's open-ended nature encourages students to engage in project-based learning, where they can design and execute their projects, from constructing historical landmarks to simulating ecosystems. Teachers can set challenges that require students to apply critical thinking and creativity to solve problems, such as building a sustainable city or creating a functioning Redstone circuit.

f. **Global Connection**:

Minecraft Education Edition often hosts global challenges where students from around the world can participate in collaborative projects, such as building a world heritage site or solving environmental issues. Through these global collaborations, students gain insights into different cultures and perspectives.

g. **Customizable Learning Environments**:

Teachers can create or download custom worlds tailored to specific lessons. These worlds can be designed to teach anything from basic arithmetic to complex scientific theories. The game can be adapted to fit various educational contexts, from primary schools to higher education.

h. **Engagement and Motivation**:

The game mechanics, such as building, crafting, and exploring, keep students engaged and motivated to learn. Students can pursue their interests within the game, leading to personalized learning experiences that cater to individual strengths and passions (Mojang

Studios, n.d.)

Educational Impacts of Minecraft Education

Classrooms across the globe use Minecraft Education Edition to teach a range of subjects in an engaging manner. Because of its adaptability, educators can use it to improve student engagement and learning in a variety of areas, from science and math to art and social studies (Mojang Studios, n. d.).

Access and Availability of Minecraft Education

Minecraft Education Edition is available through direct licensing, volume licensing, or subscription. It is compatible with a variety of operating systems, such as Windows, macOS, iPad, and Chromebooks, ensuring broad accessibility for teachers and learners alike (Mojang Studios, n.d.).

ii. Toca Boca Nature

Toca Boca Nature was developed by the Swedish digital toy manufacturer Toca Boca, which is well-known for producing creative and interactive apps for children. Toca Boca is primarily concerned with creating applications that promote creativity, exploration, and unrestricted play. It was created to give children an enjoyable and educational experience that promotes discovery and knowledge of the natural world and its ecosystems (Toca Boca, n.d.).

The following are some of the educational features of Toca Boca Nature:

a. **Environmental Awareness:**

The app allows children to explore and interact with various natural environments, such as forests, mountains, and lakes. This helps them understand the diversity of ecosystems and the different types of habitats that exist in nature.

b. **Creativity and Customization**

Children can manipulate the environment by changing the terrain, planting trees, and creating lakes or mountains. This creative control teaches them about how landscapes can be altered and how these changes can affect the environment. Players can create different habitats that attract various animals, teaching them about the needs of different species and the importance of suitable environments for wildlife.

c. **Understanding Animal Behavior:**

This app features a variety of animals that behave differently depending on their environment. Children can observe and interact with these animals, learning about their habits, diets, and natural behaviors. By feeding animals and observing their interactions, children can learn about basic food chains and the interdependence of species within an ecosystem.

d. **Cause and Effect Relationship:**

When players modify the environment (e.g., planting more trees or creating a body of water), they see how these changes affect the ecosystem and the animals that live there. This helps children understand the consequences of human actions on the environment.

e. **Observation Skills:**

The app includes elements such as the change of day to night and the growth of plants, encouraging children to observe and learn about natural cycles and processes over time. Children are encouraged to carefully observe the details of the environment, such as the types

of plants and animals present, which fosters attention to detail and observational skills.

f. Responsibility and Care for Nature:

By taking care of the environment and the animals within it, children learn about the importance of caring for nature and their role in protecting the planet. The app subtly introduces sustainability concepts, such as the importance of maintaining a balanced ecosystem and the long-term effects of environmental stewardship.

g. Language Development:

As children explore and describe the elements within the game, they can develop their vocabulary related to nature, animals, and the environment. The open-ended nature of the app allows children to create their own stories and scenarios within the environment, fostering narrative and storytelling skills.

h. Intuitive Learning

Toca Boca Nature encourages learning through play, making it easy for children to grasp complex ecological concepts naturally and enjoyably. The app promotes exploration without the pressure of right or wrong answers, allowing children to learn at their own pace and develop their understanding through experimentation.

Educational Impacts of Toca Boca Nature

Toca Boca apps foster creativity and imagination through open-ended play, enhancing problem-solving skills and language development. They promote social and emotional growth by simulating real-world scenarios and support fine motor skills through interactive gameplay. These apps, designed to be safe and ad-free, encourage independent learning and help children understand everyday concepts (Smith, & Johnson, 2023).

Access and Availability of Toca Boca Nature

Toca Boca apps are widely accessible on major platforms, including iOS and Android, and can be downloaded from the Apple App Store and Google Play Store. They are available for purchase or as part of a subscription, with frequent updates and new releases. The apps are designed for various age groups, making them suitable for a broad range of children. Toca Boca also provides educational resources and support through its website and customer service (Taylor, & Roberts, 2023).

iii. CBeebies Playtime

The British Broadcasting Corporation was the one who invented CBeebies Playtime. It was specifically created by the BBC's interactive and digital teams for the CBeebies brand, the organization devoted to producing programming for young children. The app offers a selection of games and activities based on well-known CBeebies TV shows, giving children a secure and instructive space to explore and learn (BBC, 2021).

Key Features of CBeebies Playtime are:

i. **Educational Content**:

The app includes various games and activities designed to support early learning in areas such as literacy, numeracy, problem-solving, and creativity. The content is aligned with the developmental needs of preschoolers, making learning fun and accessible.

ii. **Familiar Characters**:

CBeebies Playtime features characters from well-known CBeebies TV shows, such as "Hey

Duggee," "Something Special," "Teletubbies," and "Octonauts." These familiar characters help engage children and encourage them to participate in the activities.

iii. **Variety of Activities**:

The app offers a wide range of interactive games and activities that cater to different interests and learning styles. These activities include puzzles, matching games, drawing, music, and more, all designed to be both entertaining and educational.

iv. **Safe and Child-Friendly Environment**:

CBeebies Playtime is designed with young children in mind, providing a safe and secure environment for them to explore. The app is ad-free and does not include in-app purchases, ensuring that children can play without interruptions or the risk of accessing inappropriate content.

v. **Parent Engagement**:

The app includes features that allow parents to track their child's progress and see what they have been learning. This helps parents stay involved in their child's educational journey and provides opportunities for shared play and learning experiences.

vi. **Offline Access**:

Many of the games and activities in CBeebies Playtime can be played offline, making it convenient for the user (BBC, n.d.).

Educational Impacts of CBeebies Playtime

CBeebies Playtime provides significant educational benefits by enhancing early literacy, numeracy, and problem-solving skills through games based on popular TV shows. It supports cognitive development with interactive puzzles, promotes emotional and social growth by encouraging cooperation and empathy, and improves fine motor skills through touch and drag activities. The app ensures children's safe, ad-free environment, fostering independent learning and self-directed exploration. It integrates educational content with interactive play to support early childhood development (BBC, 2022).

Access and availability of CBeebies Playtime

CBeebies Playtime is widely accessible and available for download on major platforms, including iOS and Android. It can be obtained from the Apple App Store and Google Play Store. The app is designed for young children, with content tailored to various developmental stages. It is available for free, making it accessible to a broad audience. The BBC also ensures regular updates and new content to keep the app engaging and educational. Additionally, the app is part of the broader CBeebies brand, which offers various educational resources and support through its website (BBC, 2023).

Table 1 *Comparison Chart of three Video Games*

Game	**Platform**	**Target Age Group**	**Educational focus**	**Content**	**Summary**
Minecraft Education	Windows, Mac, iPad, Chromeb	6–18 years	● S**TEM Learning**: Strong emphasis on subjects like math,	● Extensive lesson plans across subjects. ● Education	**Minecraft Education** is ideal for older

Game	Platform	Target Age Group	Educational focus	Content	Summary
	ook		science, engineering, and coding. ● **Creativity & Problem Solving**: Encourages creativity through building and exploring virtual worlds. ● **Collaboration**: Promotes teamwork and collaboration among students in a shared virtual environment. ● **Real-World Simulations**: Allows the creation of simulations and models to understand real-world concepts.	al worlds and activities designed to align with curriculum standards. ● Integration with classroom management tools for teachers.	children, focusing on STEM, creativity, and collaboration in a structured learning environment.
Toca Boca Nature	iOS, Android	3–9 years	● **Creative Play**: Focuses on open-ended play, allowing children to explore different scenarios without rules or goals. ● **Social & Emotional Learning**: Encourages role-playing and exploration of emotions, social scenarios, and daily life activities. ● **Imaginatio**	● Wide range of apps with different themes (e.g., Toca Life, Toca Kitchen). ● No in-app purchases or advertisements, ensuring a safe and distraction-free experience. ● Each app is a self-contained experience with unique characters and	**Toca Boca** is more suitable for younger children, emphasizing imaginative play, social-emotional learning, and creativity in a more informal and playful manner.

Game	Platform	Target Age Group	Educational focus	Content	Summary
			n & Exploration: Children can create their own stories and environments, fostering creativity and imagination.	environments.	
CBeebies	TV, iOS, Android, Web	0–6 years	● **Early Childhood Education**: Focuses on early learning through age-appropriate content. ● **Language Development**: Promotes vocabulary and language skills through storytelling and interactive games. ● **Numeracy & Basic Skills**: Teaches basic counting, shapes, and colors through fun and engaging content. ● **Social Skills**: Encourages sharing, friendship, and understanding through various shows and games.	● Includes a mix of educational TV shows, interactive games, and creative activities. ● Characters from popular children's TV shows engage children in educational content. ● Safe and age-appropriate content curated by the BBC.	**CBeebies** caters to early childhood, providing foundational learning in a fun, engaging way through TV shows and interactive games designed to promote early cognitive, language, and social skills.

Methodology of the Study

The study was quasi-experimental in nature. The researcher employed non-equivalent control group design.

Sample of the Study

The instrument used in the study was a researcher's developed achievement test. It was

developed from the fourth-grade science textbook. The questions were constructed on the constructed response pattern.

Data Analysis

Data were analyzed, and results were presented in tabular form.

Table 2 *Comparison between the control and experimental groups based on the pretest scores*

Items	Total Scores	Groups	N	Mean	SD	*t*	df	*p*
The sum of pretest items	27	Control	35	3.23	1.21	- .32	72	.74
		Experimental	39	3.33	1.53			

Table 2 compares the mean scores of the control and experimental groups on a pretest. Levene's Test for Equality of Variances yielded a significance value of .74, larger than .05, so equality of variances was assumed. The p-value for the control and experimental groups was found to be .74. The control group consisted of 35 participants, with a mean score of 3.22 and a standard deviation of 1.21. The experimental group, on the other hand, included 39 participants, with a mean score of 3.33 and a standard deviation of 1.52. The t-value for the comparison between the two groups was - .32, with 72 degrees of freedom. However, this result was not statistically significant since the p-value was greater than .05. So, it can be concluded that there was no statistically significant difference seen between the groups before the treatment.

Table 3 *Comparison between the control and treatment groups based on the post-test scores*

Items	Total Scores	Groups	N	Mean	SD	*t*	df	*p*	Eta^2
The sum of post-test items	27	Control	35	12.71	1.42	- 50.97	50.42	.000	.97
		Experimental	39	26.46	.75				

Table 3 compares the mean scores of the control and experimental groups after the intervention. Levene's Test for Equality of Variances yielded a significance value of .000, less than .05. Therefore, equal variances were not assumed. The p-value for both the control and experimental groups was 00. The control group consisted of 35 participants, with a mean score of 12.71 and a standard deviation of 1.42. The experimental group, on the other hand, included 39 participants, with a mean score of 26.46 and a standard deviation of .75. The t-value, calculated with 50.42 degrees of freedom, was - 50.97. Given that the p-value is less than 0.05, it may be concluded that there was a statistically significant difference between the mean achievement scores of the groups after the treatment. The effect size (Eta^2) had a value of .97. The observed impact size was substantial, indicating a significant improvement in academic performance within the treatment group.

Findings of the Study

Based on analysis of data, it was found that:

i. Both control and experimental groups had similar mean achievement scores before the treatment.

ii. The experimental group performed better than the control group after the treatment.

iii. The magnitude of the effect was substantially larger ($Eta^2 = .97$)

Conclusion

Based on the findings of the study, it was concluded that using video games as a teaching tool in the classroom substantially affects the students' performance.

Discussion

Video games in elementary science education have shown significant potential in enhancing students' understanding and retention of scientific concepts. Video games can effectively convey scientific concepts, potentially improving students' comprehension and long-term memory compared to traditional methods. Games often require players to engage in problem-solving and critical thinking, skills that may transfer to real-life situations and contribute to overall cognitive development.

There are ethical concerns regarding screen time, data privacy, and the need for a balanced approach to learning that incorporates various teaching methods. Video games have intrinsic qualities like interactivity and amusement that captivate students, making them highly motivating and engaging. Games offer virtual hands-on experiences that allow students to explore scientific phenomena in a safe, controlled environment, which is beneficial for difficult or dangerous concepts to replicate in traditional settings. Video games can tailor content to individual students' abilities and progress, accommodating different learning styles and enabling self-paced learning. While video games can enhance science learning, they should be used as a supplementary tool alongside conventional teaching methods. An optimal approach integrates games with hands-on activities and teacher-led instruction.

The study suggests that educational video games are a valuable tool for learning science, providing motivation, engagement, and interactive experiences that support cognitive development.

Recommendations

i. **Integrate Video Games with Curriculum Objectives**: Design and select video games that align with specific curriculum objectives and scientific concepts being taught. Ensure that the games complement the educational goals and reinforce key learning outcomes.

ii. **Balance Screen Time with Traditional Learning**: Implement a balanced approach using video games as a supplementary tool rather than replacing traditional teaching methods. Combine game-based learning with hands-on experiments, teacher-led instruction, and other interactive activities to create a well-rounded educational experience.

iii. **Focus on Problem-Solving and Critical Thinking**: Choose games emphasizing problem-solving and critical thinking skills. Incorporate reflective activities where students can discuss and analyze how the skills used in the game apply to real-life scientific challenges

and situations.

iv. **Address Ethical Concerns**: Develop and follow guidelines to address ethical concerns related to screen time and data privacy. Ensure that game usage is monitored, and establish time limits to prevent excessive screen time. Be transparent about data collection practices and prioritize the safety and privacy of students.

v. **Personalize Learning Experiences**: Utilize video games that offer adaptive learning features to cater to individual students' abilities and progress. Provide opportunities for students to engage with content at their own pace and according to their learning needs while also offering support and guidance as needed.

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