



Research Article

Improving Conceptual Understanding of Science and Math through Game-based Learning among 2nd Grade Students

Sana Amin ¹, Iftikhar Ahmed Baig ², Hina Amin ^{1, *}

¹Virtual University of Pakistan

²Superior College, Defense Road Campus, Lahore, Pakistan

Abstract

This study investigated the impact of game-based teaching on the academic performance of 2nd-grade students in Science and Math at a private school in Lahore. Employing a quantitative, experimental design within the positivism paradigm, it utilized a non-equivalent pretest- posttest control group design. The independent variable was game-based teaching, while the dependent variable was students' academic achievement in the subjects. Two sections of students (30 each) were randomly assigned as a control group (traditional teaching) and an experimental group (game-based teaching). The intervention lasted three months, during which the curriculum content for Math and Science was delivered differently to each group. Pre- tests and post-tests were developed and validated to assess students' performance before and after the intervention. Statistical analyses, including paired-sample t-tests and independent sample t-tests, were conducted to evaluate the hypotheses. Results indicated that the experimental group demonstrated significant improvement in academic performance compared to the control group. The study concludes that incorporating games into education enriches the learning experience and fosters essential life skills alongside academic knowledge.

Keywords: Game based teaching and learning, Educational games, Academic performance, Gamification.

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*Corresponding Email:

hina.amin@vu.edu.pk

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Introduction

In all over the world many institutions are focusing on different programs and courses related to educational games. The interest of students, teachers, researchers and policy makers in educational games is increasing daily. Educational games play a significant role in modern learning due to their ability to enhance traditional educational methods by offering interactive and engaging experience. Gamification is the process of applying game elements to non-gaming elements. It is primarily used to increase user engagement and motivation (Takbiri et al., 2023). The new generation is emerging with a strong background in gaming. Therefore, integrating educational games into the curriculum is more advisable than ever to enhance the teaching and learning process (Miller, 2008). According to Glass et al. (2013), 97% of the population of teenagers aged 12-17 and 72% of the world online population were reported playing video games in 2008. This ratio is increasing daily with the availability and advancement in technological field. Frequently playing games promotes faster visual information processing and logical comprehension of given tasks. Shakhmalova and Zotova (2023) carried out comprehensive research on the effects of digital educational games on student motivation, highlighting their effectiveness in the educational sector. Student motivation is a vital component of the learning process, affecting both their engagement with educational tasks and their overall perception of the learning experience. As a new tool in education, digital educational games hold promises for improving

students' motivation to learn. Nowadays, game-based learning, teaching and gamification tools play a crucial role in engaging young learners and supporting their primary education. Interest in traditional classroom teaching is declining among youngsters, as they seek more interactive and engaging educational content. As a result, they increasingly prefer game-based education and learning through gamification (Fiuza-Fernández et al., 2022). Game-based teaching can enhance students' interest in learning and foster their desire for knowledge (Fiuza-Fernández et al., 2022). This study aimed to investigate the importance of game-based teaching at a primary level in a private school in Lahore. It analyzes the impact of game-based teaching on students' performance in two major subjects' mathematics and science. Moreover, the result of this study was useful for curriculum development wings to add more games-oriented content in the syllabus. The findings of the research highlighted the real issues prevailing in the effective instructional strategies at primary level and aimed to provide recommendations to improve instructions at primary level for students. This study was also beneficial for students to train them to construct their own learning by setting pace. Moreover, it helped to encourage students to be independent learners and make them problem solvers.

According to Takbiri et al. (2023), gamification is a process applied to various games to enhance students' interest and motivation toward gameplay. Gamification and game-based learning are applied across various subject areas, such as science and mathematics, to enhance students' critical thinking skills and foster their interest in learning. By incorporating game-based learning, education becomes more accessible, engaging, and enjoyable for students (Kim & Park, 2021). In traditional methods tutors are considered as centered instruction. Learners get education from the teachers through lectures. The overall learning of the learner usually depends on the teacher who facilitates their student with different helping materials. The traditional learning strategy follows a one-way communication model, where the instructor delivers the material to the audience (Gholami et al., 2016). Traditional based teaching approach, the teacher delivers notes and assigns homework tasks (Gregorius, 2017).

While learning through games is the most active method to involve students. Teaching through games is basically the best method which usually focuses on creating adults that have master minds. Games focus on intelligence and acquaintance rather than grades. Hamari et al. (2016) noted that the digital game-based learning strategy focuses on activating prior knowledge and experience while providing instant feedback. It can also be applied to solving real-life problems. The key differences between traditional learning and game-based learning are shared in Table 1.

Table 1. Differences between traditional learning and game-based learning.

Traditional learning	Game based learning
In this learning method sometimes different helping material in the form of games is provided to support some abilities in the students.	In game-based learning, students choose different games, modify these games themselves to learn different concepts easily and evaluate their certain talents.
In this method games are mostly used as prizes or additionally used.	The whole process of learning totally depends on different types of games from start of learning to end.
Rules and regulations are delivered to students before starting the lesson.	Rules are made during playing games by the students.
Students are bound to learn the decided topic.	Students are not bound to learn the decided topic.
More theory is involved. No activity is performed by the students.	Less theory. Observation and demo based.
Limited motivation towards studies.	Enough motivation and stimulation.
No connection to real life experiences.	Close to real life experiences.
Instructor –centered education	Learner centered education

Game based learning makes students in charge of their own learning. Game-based instructional practices either for revision purposes or lectures help the student to become actively involved in their learning. This will make them eventually self-regulated learners. Furthermore, game-based teaching captures the student's attention and helps in retention as students are constructing their own knowledge. This experiential learning helps students to explore those ideas which are difficult. Holland et al. (2003) noted that games are helpful in students' learning to perform multiple tasks, and this helps them to be cognitive, flexible and problem solvers. Another interesting aspect is that game based teaching helps students to be independent learners. Chuang and Chen (2007) said that digital games have a great impact on students' learning and achievement. It was also noted in a study conducted by Glasgow University that game-based teaching even used for social sciences subjects resulted in better communication and interaction skills among higher grade students.

According to Sotos-Martinez et al. (2023), a study was conducted to examine the impact of gamification on students in physical education. The findings revealed that gamification significantly increased students' motivation toward the lecture. In Pakistan, although a positive perception towards digital educational games persists, a variety of barriers exist in proper implementation of game-based teaching in Pakistani educational context particularly at school level. Currently, some private schools are making use of online available games, as a supportive instructional tool to enhance the comprehension of concepts. Mostly, games-based teaching is not used exclusively in the place of lectures but used as an aid to facilitate the lecture process. The disciplines which are taught with the aid of games in different schools and colleges include Literacy, Numeracy, Robotics, General Knowledge, Geography and Science. However, the acceptance of educational games on a wider scale as replacement of lecture solely is dependent on certain variables such as a well-established infrastructure, teacher training, positive teacher perceptions and experiences, the extent to which the curriculum relevant resources are explored and implemented, efforts invested at individual school level and the extent of support at government level (Hammad, 2017).

According to Grace (2019), game-based learning is a method of acquiring new concepts and skills through both digital and non-digital games. Incorporating various game applications in education can enhance both learning and teaching outcomes. According to Kühn et al. (2018), game-based educational videos help students develop problem-solving skills and enhance their creativity in answering questions. If a student is unable to complete a level, they are given multiple opportunities to retry until they achieve the correct answer and successfully complete the game. This approach promotes in-depth understanding of the topic, leading to long-lasting learning.

Game-based learning has a significant impact on students' independent learning and emphasizes student-centered learning (Coleman & Money, 2020). Game based learning tackles these challenges by utilizing digital tools and online platforms to foster a dynamic learning environment that promotes active learning practices (Delgado-Algarra, 2020) and improves students' academic success (Sylvén & Sundqvist, 2012; Ali et al., 2021). Game based learning is more enjoyable, fun engaging and interactive. By immersing students in engaging activities, game-based learning fosters deeper understanding, improves problem-solving skills, and promotes collaboration. It also helps sustain motivation, as students are driven by a sense of achievement and progress (Brangier & Marache-Francisco, 2020; Osipovskaya & Miakotnikova, 2020; Tundjungsari, 2020). In Pakistan though at limited level but the concept has been caught, and game-based teaching has been started at selected schools. So, there was no need to find out the difference between academic performance of students through game-based teaching and traditional lecture method at primary level of math and science concepts.

Theoretical Framework

This study is based on Constructivist theory, developed by Jean Piaget and further expanded by Lev Vygotsky, emphasizes that learning is an active, constructive process where learners build new knowledge based on their prior experiences. In the context of game-based teaching, constructivist principles align well with the idea that students learn best through interactive, hands-on experiences social interaction and learning process rather than passive instruction. In a student-centered classroom, learners are encouraged to engage in academic

activities with the guidance of facilitators. Piaget and Vygotsky both emphasize that students should gain knowledge through their own experiences by actively participating in learning activities (Burhanuddin et al., 2021). Constructivist theory transforms the focus from passive learning to active, student-centered learning, where students construct knowledge through meaningful experiential learning. It fosters a more engaging and effective learning environment, preparing students for real-world challenges. Long (2016) suggests designing pedagogic tasks as simplified versions of the target tasks. These tasks are then sequenced by increasing complexity, gradually preparing learners to successfully engage with the final target tasks. 21st-century teachers should create interactive learning experiences that encourage students to think creatively and develop problem-solving skills. The impact of constructivist theory enhances deep understanding rather than surface-level memorization and promotes critical thinking, creativity, and independent learning. It also encourages lifelong learning by making education engaging and relevant and builds social and communication skills through collaboration.

In game-based learning, constructivism based on following principles:

1. **Active Learning:** Games provide students with engaging, problem-solving experiences where they must think critically, make decisions, and apply knowledge rather than just memorize information.
2. **Experiential Learning:** Games create simulated environments where learners experiment, make mistakes, and refine their understanding through trial and error.
3. **Social Interaction and Collaboration:** Many educational games encourage peer interaction, teamwork, and discussions, supporting Vygotsky's idea that social interactions are crucial for cognitive development.
4. **Intrinsic Motivation and Engagement:** Games make learning fun and meaningful, increasing students' motivation to explore, solve problems, and persist in learning tasks.
5. **Assessment through Application:** Instead of relying on rote memorization and standardized testing, constructivist classrooms use project-based assessments, portfolios, and real-world applications to evaluate students' understanding.

In this theory different teaching strategies are applied. Such as:

1. **Inquiry-Based Learning:** Encouraging students to ask questions, investigate, and find answers through exploration.
2. **Project-Based Learning (PBL):** Students engage in long-term projects that require research, collaboration, and critical thinking.
3. **Collaborative Learning:** Group discussions, peer teaching, and teamwork to share and construct knowledge.
4. **Experiential Learning:** Hands-on activities, role-playing, simulations, and real-world problem-solving experiences

Conceptual Framework

The conceptual framework of the study is as follows as in Figure 1.

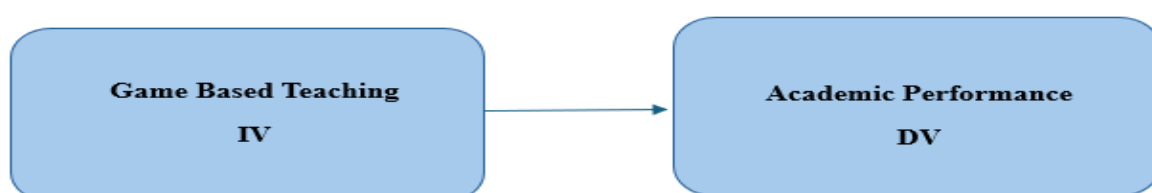


Figure 1. Conceptual framework.

Research Objectives

Objective of the study was to examine the effect of game-based teaching on students' academic performance in comparison to traditional teaching methods.

Hypotheses

Ho 1: There is no significant difference in academic performance of 2nd grade students of mathematics subject in pre-test of control and experimental group

Ho 2: There is no significant difference in academic performance of 2nd grade students of mathematics subject in post-test of control and experimental group

Ho 3: There is no significant difference in academic performance of 2nd grade students of science subject in pre-test of control and experimental group

Ho 4: There is no significant difference in academic performance of 2nd grade students of science subject in post-test of control and experimental group

Ho 5: There is no significant difference in academic performance of 2nd grade students of science subject in pretest and posttest of experimental group

Ho 6: There is no significant difference in academic performance of 2nd grade students of mathematics subject in pretest and posttest of experimental group

Ho 7: There is no significant difference in academic performance of 2nd grade students of science subject in pretest and posttest of control group

Ho 8: There is no significant difference in academic performance of 2nd grade students of mathematics subject in pretest and posttest of control group

Methodology

Pretest- posttest experimental research design (non-equivalent and non-randomized) was used to conduct this study. The independent variable in this study was game based teaching and the dependent variable was students' academic achievement in mathematics and science subjects. The measurement has been made prior to the intervention and again after the implementation of game-based teaching.

Population and Sample

All the students of grade II (300 students in 10 sections) enrolled in a private school was the group of the study. For the sample purpose two sections (randomly) were selected and assigned/named as control and experimental group. Each group has 30 students of mixed abilities. Both male and female students were considered participant for the sample of study. Both groups had the same number of students (30, 30) as per school policy.

Experimental group, Control group and Intervention

The students of the experimental group were taught with educational games only (mathematics and science) and it was called group A. Control group students were taught with traditional teaching method (lecture) and it was called group B. Content of science and math subjects of grade II level was selected and taught by using educational games. In mathematics following content was taught (Addition, Shapes Number Patterns, Division, Place Value, Money, Subtraction, Multiplication, Fraction, Time, and Graphing) and in Science (Food and Diet, Food Pyramid, How Plants Grow, Plant World, Animal World, The Solar System, Skeleton and Bones, Human Body Health and Growth, Plant and Animal differences, Solid, Liquid and Gases, Properties of Materials, Light and Dark, Changing Sound, Rock, Minerals and Soil) was taught. Educational games related to these concepts were carefully chosen by keeping in mind the cognitive level of students. For the intervention, the websites mentioned were utilized are <https://www.sciencekids.co.nz/>, <https://bestkidswebsites.com/kids-astronomy/>, <https://healthyeating.com/>, <https://www.mathplayground.com/>, <http://ww1.mathplay.com/>, <https://www.abcya.com/>, and <https://www.education.com/>.

All the games were self-explanatory and directional. Students were only guided to move to the next level to complete concept/game. Intervention was given for a period of three months. The duration of treatment was 35 minutes per day thrice a week. Two tests i.e. pre –test and post- test were administrated before and after the intervention to measure the academic performance of students in both subjects (mathematics and science).

Data Collection

The control group and experimental group students were the data collection source. The researcher personally engaged herself in data collection and intervention process. The collected data was analyzed by Statistical Package for Social Sciences (SPSS) 24. Both types of statistics, i.e. descriptive and inferential statistics, were used to analyze data. Statistical tests i.e. Paired-sample t-tests and independent sample t-tests were used to accept or reject research assumptions (hypothesis).

Results and discussion

Table 2. Independent Sample T-tests for Pre-test and Post- test Math.

Variables	groups	N	Mean	Std. Deviation	df	t	Sig.
Pretest math	experimental group	30	14.6000	4.31197	56.814	-.526	.601
	control group	30	15.2333	4.98746			
Post test math	experimental group	30	28.0333	2.98829	46.609	9.477	.000
	control group	30	17.7500	5.13734			

Table 2 shows that the t-value is (-0.526) and p-value (0.601) it shows the result of a t-test comparing the pre-test scores between the two groups. So, null hypothesis Ho1 is accepted. In posttest math scores the t-value is (9.477) and p-value (0.000) it shows the result of the t-test comparing the post-test scores between the two groups. Therefore, the null hypothesis Ho2 is rejected.

Table 3. Independent Sample T-tests for Pre-test and Post-test Science.

variables	groups	N	Mean	Std. Deviation	df	t	sig
Pretest science	experimental group	30	19.4333	4.43873	.975	58	.333
	control group	30	18.4000	3.73797			
Post test science	experimental group	30	28.0000	2.39252	48.97	10.251	.000
	control group	30	19.6167	3.78674			

Table 3 shows that the t-value is (58) and p-value (0.333) it shows the result of a t-test Table 3 .shows comparing the pretest science scores between two groups. So, null hypothesis Ho 3 is accepted. In posttest science scores the t-value is (10.251) and p- value (0.000) it shows the result of the t-test comparing the posttest science scores between two groups. Therefore, the null hypothesis Ho 4 is rejected.

Table 4. Paired sample test for pre- and post- tests of science and Math (Experimental Group).

Variables	Mean	N	SD	df	t	Sig. (2-tailed)
Post test science Experimental Group	28.0000	30	2.39252	29	10.900	.000
Pretest science Experimental Group	19.4333	30	4.43873			
Post test math	28.0333	30	2.98829	29	17.157	.000

Experimental group	14.6000	30	4.31197
Pretest math			
Experimental Group			

As shown in Table 4, a paired-samples t-test was conducted to compare science and math scores in the pre-test and post-test for the experimental group. There was a significant increase in science scores $t(29) = 10.90$, $p < .001$ and math scores $t(29) = 17.16$, $p < .001$. It means Null hypothesis H_{05} and H_{06} are rejected.

Table 5. Paired sample test for pre- and post- tests of Science and Math (Control Group).

Variables	Mean	N	SD	df	t	Sig. (2-tailed)
Post test science	19.6167	30	3.78674	29	3.079	.005
Control Group	18.4000	30	3.73797			
Pretest science						
Control Group						
Post test math	17.7500	30	5.13734	29	3.18	.003
Control group						
Pretest math	15.2333	30	4.98746			
Control group						

As shown in Table 5, a paired-samples t-test was conducted to compare science and math scores in the pre-test and post-test for the control group. There was a slightest difference in of science scores $t(29) = 3.079$, $p < .001$ and math scores $t(29) = 3.18$, $p < .003$. It means Null hypothesis H_{07} and H_{08} are accepted.

Discussion

The first objectives of this study were to explore the motivation level of students towards game-based teaching, and it is supported by findings of this study that experimental group which were taught through game-based teaching showed greater improvement in their performance. The major finding of this study was the improved academic performance in subjects of science and math when students were taught through game-based teaching. Results showed the alignment with the literature as quoted by Chiong (2010) that playing games and enjoying them is considered one of the most important parts of human response. Sung and Hwang (2013) stated that educational games that use computers as mass media are beneficial to enhance the learning process of students and affect the leaning outcomes. Games being interactive, competitive and collaborative motivate and support student's interests towards their learning. Game based education helps students to learn more actively and with great interest, it results in a profound intuition that will probably be available with the use of old procedures (Papastergiou, 2009). Game-based learning has a significant impact on students' independent learning and emphasizes student-cantered learning (Coleman & Money, 2020). Game based learning tackles these challenges by utilizing digital tools and online platforms to foster a dynamic learning environment that promotes active learning practices (Delgado-Algarra, 2020) and improves students' academic success (Sylvén & Sundqvist, 2012; Ali et al., 2021). Gamification transforms education into an engaging experience that enhances personalized learning by providing instant feedback and encouraging collaboration and friendly competition among students. Meanwhile, storytelling captivates students, creating a more immersive and emotional learning experience that improves comprehension and retention of the material. Additionally, Boller and Kapp (2018) reported that game-based teaching provides engagement and connection on multiple levels, and this is valuable in today's dynamic environment. In addition, Game-based learning can facilitate the connection between theoretical concepts and practical application, enabling students to utilize their knowledge in real-world situations (Barz et al., 2023).

Conclusions and Recommendations

The aim of this research was to see the effectiveness of game-based teaching on students' academic performance in math and science subjects at primary level. It is concluded from this research that educational games are proven to be a valuable technological tool to motivate students for improved academic performance. Future research should include the acceptance of educational games on a wider scale as replacement of lecture solely is dependent on certain variables such as a well-established infrastructure and administration policy of any organization. Additionally, positive teacher perceptions, teacher training and their experiences are also important to implement this teaching strategy on a regular basis. Efforts should be made at individual and curriculum level to explore and add relevant resources into national curriculum for uniformity. This study is based on constructivist theory and Active Learning. Games provide students with engaging, problem-solving experiences where they must think critically, make decisions, and apply knowledge rather than just memorize information. This study can be replicated at secondary and even at higher secondary level to see the impact of game-based teaching on students' academic performance, retention and higher order thinking skills. Comparison can be made on the urban and private schools' students, and their academic performance can be compared. This approach (game-based teaching) further explores and even used for social sciences subjects to improve their communication, interaction skills and behavior modification among higher grade students. It is recommended that Game-based teaching should be seamlessly aligned with educational curricula to ensure that learning objectives are effectively met while maintaining student engagement. Educators should receive professional training on designing, implementing, and assessing game-based learning strategies to maximize their impact. More studies should focus on the long-term effects of game-based teaching on student achievement, motivation, and cognitive development. Schools and parents should be involved in supporting and encouraging game-based learning strategies to create a more holistic educational experience.

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