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The Effect of Games and Simulations in Learning Mathematics: A Quasi-Experimental Study

Nidup Dorji[1], **Karma Sonam Rigdel**[2]✉

[1] nidupdorji1988@education.gov.bt
Ramjar Middle Secondary School
Bhutan
[2] ksrigdel2018@education.gov.bt
Wangbama Central School
Bhutan
✉ Corresponding author

ABSTRACT: *This study aimed to investigate the effect of games and simulations on the academic achievement of secondary school students in mathematics. Employing a quasi-experimental design, the study utilized both an experimental group (EG) and a control group (CG) to assess the effectiveness of games and simulations in learning mathematics. A total of 62 grade nine students participated. The EG was exposed to quiz games, problem-solving games, polyprod games, and PhET simulations for teaching polynomials, while the CG followed traditional teaching methods. Data were collected using mathematics achievement test scores and a survey questionnaire. Descriptive and inferential statistics were used to analyze the data. The findings indicated that students had positive perceptions of using games and simulations in learning mathematics, with an overall mean score (M = 4.18, SD = 0.71). The EG showed significantly higher mathematics achievement than the CG, demonstrating the effectiveness of games and simulations in learning (p<0.05). Additionally, a strong positive correlation (r = 0.96) was found between students' perceptions of games and simulations and their mathematics achievement. The study concludes with implications and recommendations for future research.*

KEYWORDS: Attitudes, games, simulation, mathematics achievement test, traditional method.

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1. Introduction

In contemporary education, technology integration is revolutionizing traditional teaching methodologies. Among various technological tools, games and simulations have emerged as dynamic and engaging platforms with the potential to enhance the learning experience, particularly in mathematics (Vlachopoulos & Makri, 2017). Traditional methods of teaching mathematics often rely on rote memorization, potentially hindering genuine comprehension and interest in the subject. Zarraonandia et al. (2022) suggest that games and simulations offer an interactive and immersive alternative, engaging students in virtual worlds, mathematical puzzles, and practical scenarios. Aligned with constructivist and experiential learning theories, these digital tools empower learners to actively construct their mathematical knowledge through hands-on experiences.

In the 21st century, mathematical proficiency demands that students apply learned mathematics to real-world problems, innovate, think creatively, and adaptively participate in continually shifting economies (Bustamante et al., 2022). This shift indicates a need for a more conceptual and flexible understanding of mathematics, along with innovative teaching and learning approaches. Games and simulations are promising strategies for making mathematics learning engaging, joyful, and fun (Liu et al., 2011).

However, concerns within the Ministry of Education (MoE) in Bhutan highlight the struggle to ensure quality education. The Royal Education Council (REC, 2010) confirmed that student performance was not up to grade level and lacked critical thinking, communication skills, and problem-solving abilities. The Bhutan Council of School Examinations and Assessment (BCSEA, 2019, 2020 & 2021) reported declining national mean marks in mathematics for class X: 56.83% in 2019, 52.02% in 2020, and 46.85% in 2021. As technology evolves, integrating games

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and simulations into mathematics education becomes increasingly feasible. This study aims to contribute empirical evidence on their impact, offering insights into best practices for implementation.

1.1 Research Problem

Despite advancements in educational methodologies, mathematics education continues to struggle with engaging students and fostering deep comprehension of concepts. Traditional instructional approaches often fail to capture students' interest and address diverse learning styles. Recognizing this, the integration of games and simulations into mathematics instruction has emerged as a promising avenue (Koskinen & Pitkäniemi, 2022). However, empirical research assessing the tangible impact of games and simulations on mathematics learning outcomes is limited (Vlachopoulos & Makri, 2017).

In the Bhutanese context, the MoE is struggling with a significant concern regarding the declining performance of students in mathematics, as evidenced by the consecutive deterioration in national mean marks over the past three years, reaching 46.85% in 2021. Despite being a core and compulsory subject, the poor academic achievements are attributed to the traditional teaching methods employed by teachers. The prevalent use of conventional chalk-and-talk approaches, characterized by a teacher-dominated environment, limits students' critical thinking development and fails to cater to individual differences and learning styles (Utha et al., 2016).

Additionally, a study by Dolma (2016) emphasized that the issue lies not in the curriculum framework but in its implementation in the classroom. Similarly, Jameel and Ali (2016) revealed that teachers often use methods that hinder students' understanding of abstract mathematical theories, leading to negative attitudes and low performance. Moreover, the lack of practical and exciting teaching methods contributes to this problem, and the need for change is emphasized by the suggestion that incorporating games and simulations into the teaching of mathematics could enhance learning achievement (Ünal, 2017). Therefore, the current study aims to investigate the effects of simulation and games instructional strategies in mathematics classes as a potential solution to the pressing issue of low academic achievement in Bhutan.

1.2 Aims and Objectives:

This study aims to ascertain whether there are differences in achievement in mathematics when taught using games and simulations. Specifically, it investigates the effectiveness of simulation and games in teaching Class IX mathematics, examines students' views on using simulations and games, and explores the relationship between students' views and academic achievement in mathematics.

Research Questions:

1. Is there a significant difference in the academic achievement of the control group and the experimental group?

2. What are students' perceptions of simulations and games in learning mathematics?

3. Is there a significant relationship between students' perceptions and academic achievement in mathematics for the EG?

1.4 Significance of the Study

Emphasizing the use of simulation games in mathematics education is anticipated to improve mathematics teaching and learning in secondary schools. The study aims to demonstrate the importance of using simulations and games to enhance mathematics teaching and learning. It also provides insights for future researchers on how simulation and games as a teaching approach can improve mathematics performance.

2. Literature review

2.1 Games and Simulations in Education

In the 21st century, simulation has gained increasing popularity as an effective instructional tool in education across various disciplines. It is particularly notable in higher education, with a focus on Science, Technology, Engineering, and

Mathematics (STEM) subjects (D'Angelo et al., 2014). Simulation-based learning is recognized as a valuable approach to developing complex skills and overcoming traditional learning drawbacks (Chernikova et al., 2020).

Educational games and simulations have found prominence in mathematics education, proving to be suitable for promoting achievements in problem-solving, algebra, strategic and logical skills, geometry, arithmetic, and critical thinking (Vankúš, 2021). Scholars and educators have offered varying definitions of simulation depending on the academic discipline. According to Beaubien and Baker (2004), simulation is technology that replicates real-life characteristics. BMC Medical Education (2016) defines simulation-based education as a pedagogical approach enabling students to practice learned abilities in real-life circumstances. Cook et al. (2013) provide a more precise definition, describing simulation as an instructional tool or device with which learners physically interact to simulate real-life situations, emphasizing the importance of interacting with reliable elements.

In educational institutions, schools, and homes, a wide range of educational games are used. The primary goal of using games in education is to improve critical thinking by encouraging students to think beyond the box when teaching a certain subject. There are other games that can be used that limit to improving knowledge in a specific subject and the most popular ones are math games. Yue and Zin (2009) discussed that games like chess cannot be viewed as educational games as these improve logic skills, reasoning, and other traits valued in education but they are not considered as educational because they do not deliver content or relay curriculum material. Games that incorporate curriculum content or other educational material are referred to as educational games (Michel, 2016).

Educational games are regarded as novel teaching technology with enormous potential in a range of subjects such as science, mathematics, history, and geography (Becker, 2007). Games have become an essential topic in the educational technology domain since they boost students' motivation, engagement, and achievement in a variety of subject areas, and they are also considered enjoyable, and motivating as well as ensuring full participation. According to Thomas (2017), game-based learning is significantly more stimulating for students nowadays than traditional academic education. According to Barab et al. (2010), educational games are a technological and methodological tool for developing immersive, interactive, and experientially consequential teachings. Games can engage and motivate students as an instructional tool (Thomas, 2017), hence learning through games is more likely to be retained. Games are pedagogical and artificial instruments that feature conflict, rules, and predetermined outcomes (Sauve et al, 2007).

In recent years, the usage of games in higher education has increased. This includes educational games (Çankaya & Karamete, 2009), digital game-based learning (Yang, 2012), and applied games (van Roessel & van Mastrigt-Ide, 2011). Furthermore, video games (Biddiss & Irwin, 2010) or even next-generation video games (Bausch, 2008) are included in the category of games. Concerning web-based games, the technological platforms that implement digital game code include computers and consoles (Vlachopoulos & Makri, 2017). They may be played on mobile phones and other mobile gaming devices using a web browser (Willoughby, 2008). With the advancement of technology, the use of digital games is getting popular in the education in 21st century.

2.2 Effect of Simulation and Games in Mathematics

Despite the increasing prevalence of games and simulations in education, there is ambiguity about whether these tools positively influence students' learning. Molenda and Sullivan (2003) mentioned that among problem-solving and integrated learning systems, games and simulations are among the least utilized technology applications in education. Many students harbor a dislike for mathematics, considering it uncomfortable and challenging (Sedig, 2008). Mathematics anxiety, stemming

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from the theoretical nature of how it is typically taught, poses a global problem affecting teaching and learning styles, particularly in developing countries (Mohameda & Tarmizi, 2010).

To address the challenges in mathematics education, incorporating play and simulation into lessons is proposed as a means to avoid dull and confusing learning experiences (Costu et al., 2009). Learning games that enhance group collaboration, engagement, and participation, and align with course goals are highlighted as a useful teaching method (von Wangenheim et al., 2012). Numerous studies have shown that educational games, especially digital ones, are effective in enhancing learning. They create a desire to study, inspire interest, and significantly impact students' engagement and interactivity (Bourgonjon et al., 2010, Navidad, 2013). Interactive teaching through games and simulations is suggested as a means to prevent absenteeism, boredom, and reluctance to learn.

Games have long been recognized for fostering mathematical reasoning and are viewed as valuable for discovery-based learning (Kamii & Rummelsburg, 2008). They create a conducive learning environment, improve performance, increase motivation, and allow collaboration (Hamalainen, 2008; Burguillo, 2010). Teachers observe that games foster collaboration amongst students and enable sustained focus on specific tasks (Millstone, 2012). While several studies report positive effects of games on learning outcomes, others do not show the same positive effects. Ke (2008) found no significant effect of educational computer games on math achievement in a study involving 5th-graders. The impact of games may vary, and controlling contextual variables is crucial in assessing their effectiveness.

Meta-analyses conducted by Adamu (2018) have shown that incorporating games into students' learning leads to significantly higher cognitive gains compared to traditional teaching methods. Similarly, Okechukwu et al. (2014) and Taclay (2013) found positive effects of mathematical games on student achievement in geometry and quadratic expressions, respectively. However, Ke (2008) suggested that the impact of educational computer games on math achievement may not be universally positive. The need to consider contextual variables, such as socioeconomic status, gender, and prior math achievement, is emphasized. Overall, the use of games and simulations in teaching is posited as a means to foster creativity, critical thinking, and motivation in learning mathematics, ultimately contributing to improved academic achievement.

2.3 Students' Perceptions of Using Simulation and Games towards Mathematics

Çankaya and Karamete (2009) stated that there is a positive correlation between students who excel in math classes and those who hold favorable perceptions toward educational computer games and simulations. Educational games and simulations can be effectively employed in conjunction with other teaching approaches to achieve instructional or educational objectives. Experimental studies in the literature, as indicated by Can (2003), support the notion that educational computer games are valuable tools for instructional purposes.

The simulation-games technique, as highlighted by Ishaq et al. (2019), has been found to significantly enhance students' perceptions and achievement in mathematics. This underscores the importance of the simulation and game environment as a teaching method that can influence students' performance and perceptions toward mathematics.

Computer games have been recognized as beneficial tools to enhance arithmetic achievement and foster positive perceptions toward math. Pareto et al. (2011) developed a teachable-agent arithmetic game that improved students' math performance and self-efficacy beliefs. Ahmad and Latih (2010) created an educational math game on fractions, and Lee (2009) evaluated a game on fractions, both reporting positive impacts on students' understanding and performance. Further, Katmada et al. (2014) conducted a study where students expressed predominantly positive perceptions about an educational game. The game was considered a useful and engaging learning tool, with students of various ages and genders endorsing and appreciating game-based learning activities.

3. Methodology

3.1 Research Design

The paradigm chosen for the study is post-positivism. As defined by Creswell (2014), positivism is defined as scientific methods grounded in empiricism and rationalism and based on the cause-effect relationship. The positivist paradigm follows the notion that every phenomenon or event has a cause that can define the effect or consequence. Since the study aimed to find out the effect of games and simulations in teaching and learning mathematics, the post-positivist paradigm proves appropriate for this study. The study used a quantitative approach as it offers a better way to address the research problems. The study involves quantifying the data collected and subjecting them to statistical treatment to support or refute alternative knowledge claims (Creswell & Creswell, 2018). Further, this study employed a quasi-experimental design to investigate the effectiveness of games and simulations in teaching and learning mathematics. Rogers and Revesz (2019) claimed that a quasi-experimental design aims to establish a cause-and-effect relationship between an independent and a dependent variable. With the quasi-experimental design, the study tries to determine the effect of simulations and games in mathematics lessons and their effects on the academic performance of students in mathematics.

3.2 Study Sample and Sampling Procedure

The target population serves as the primary data source to address the research questions. Therefore, this study's target population includes grade 9A and 9B students from one of the schools in the Haa District. Sampling involves selecting participants to make statistical inferences and estimate the characteristics of the entire population (Creswell, 2014). Due to the research design, the class functions as the study sample. Purposive sampling was employed to select two sections of ninth-grade students based on their similar academic performance in the previous year, ensuring comparability between the experimental and control groups. This approach, while limiting generalizability, was chosen to facilitate a focused investigation within a specific context. Although purposive sampling is typically associated with qualitative research, it can be appropriate for quantitative research (Palinkas et al., 2015), including quasi-experimental designs, under specific conditions. Thus, two sections of ninth-grade students were purposively involved in the study based on their academic performance in the previous year, with nearly equal mean scores of achievement in eighth grade.

3.3 Research Instruments

3.3.1 Mathematics Achievement Test (MAT)

The achievement tests, divided into pre-test and post-test categories, consisted of multiple-choice (MCQ) and short-answer questions, each worth 15 marks and administered within half an hour. These tests were based on mathematical concepts taught over a month and administered to 31 experimental group (EG) and 31 control group (CG) participants to assess the impact of the teaching intervention. The pre-test, conducted before the intervention, established a baseline of students' mathematical knowledge. The post-test, similar to the pre-test, was conducted after a month of utilizing simulations and games in teaching mathematics to measure changes in achievement levels. Participants and their guardians were informed about the study's objectives, interventions, and their rights to withdraw without consequences. To address ethical considerations, the control group was scheduled to receive the same simulations and games-based learning experiences after the study, ensuring equitable opportunities for all students.

3.3.2 Survey Questionnaires

A survey questionnaire was administered to the experimental group to gather students' perceptions on the use of games and simulations after the intervention phase. Respondents voluntarily answered the questionnaire independently via a Google Form shared in their emails. The questionnaire consisted of 15 items using a 5-point Likert Scale: strongly disagree (1), disagree (2), neutral (3), agree (4), and strongly agree (5).

3.4 Data Analysis

According to Kothari (2004), data analysis involves editing, coding, classification, and tabulation of collected data to summarize and organize field data. Since this study involved quantitative data, Statistical Packages for the Social Sciences (SPSS 25.0) were used for analysis. Data from the pre-test and post-test were analyzed for descriptive statistics such as mean and standard deviation, and inferential statistics including t-tests, correlations, and simple regression analysis.

3.4.1 Pre-test and Post-test (MAT)

Comparative statistical analyses, including boxplots, paired-samples t-tests, and independent-samples t-tests, were performed on data from the pre-test and post-test. Within-group comparative statistics utilized paired-sample t-tests, while an independent t-test compared results between the control and experimental groups before and after the intervention. Inferential statistics used a t-test with a significance level of $p < .05$ to test significance.

3.4.2 Survey Questionnaires

Mean and standard deviation were calculated from survey questionnaires on students' perceptions of using simulations and games in mathematics teaching and learning. Mean scores were interpreted using the scale range from Orlanda-Ventayen and Ventayen (2017), categorized into five levels: very poor, poor, moderate, good, and very good. Ratings of very good and good were considered positive, while very poor and poor were negative, and moderate was neutral. Pearson's correlation coefficient was interpreted using the rating scale from Sugiyono (2013), as shown in Table 2.

3.4.3 Effect Size (Cohen's d)

An effect size measures the magnitude of the difference between groups. It is particularly valuable in best-practice research as it provides a standardized measure for assessing all outcomes

Table 2. Interpretation of correlation coefficient.

Correlation coefficient value (r)	Interpretation
0.000-0.199	Very low
0.20-0.399	Low
0.40-0.599	Medium
0.60-0.799	Strong
0.80-1.000	Very strong

**Adopted from Sugiyono (2013).*

Table 3. The rule of thumb for Interpreting Cohen's d.

Cohen's d	Effect Size
Below 0.20	Small
Between 0.20 and 0.80	Medium
Above 0.80	Large

Table 1. Scale Range to Determine the Level of Students' Perception.

Level of Rating	Mean Range	Interpretation	Further Interpretation
Strongly Disagree	1.00-1.80	Very Poor	Negative
Disagree	1.81-2.60	Poor	
Not sure	2.61- 3.40	Moderate	Moderate
Agree	3.41- 4.20	Good	Positive
Strongly Agree	4.21-5.00	Very Good	

**Adapted from Orlanda-Ventayen & Ventayen (2017).*

(Cohen et al., 2007). Cohen's d, a commonly used effect size, is the ratio of the mean difference between two groups, expressed in standard deviation units. Cohen (1988) proposed a rule of thumb for interpreting effect sizes, as shown in Table 3.

3.5 Reliability and Validity

To determine the reliability of the instruments used, the researcher piloted the survey questionnaire before collecting actual data from outside the study sample. The Cronbach's alpha reliability was checked to ensure high reliability and was found to be within an acceptable range, 0.85, as suggested by Andale (2014), where acceptable Cronbach's alpha values vary between 0.70 and above. The instruments were validated by experts as reliable research tools. Both the pre-test and post-test questions were validated using Item Objective Congruence (IOC) (Turner & Carlson, 2003). The average IOC for the conceptual test was 0.91 for the pre-test and 0.92 for the post-test, indicating that the items were suitable for the study.

4. Results

4.1 Demographic Details

Table 1 presents the demographic composition of two groups, the Control Group (CG) and the Experimental Group (EG). The Control Group comprises 15 males and 16 females, while the Experimental Group consists of 14 males and 17 females, making a total of 31 individuals per group and an overall sample size of 62.

Table 1. Demographic Information

Gender	CG	EG	Frequency	Percent
Male	15	14	30	48.4%
Female	16	17	32	51.6%
Total	31	31	62	100%

4.2 Test of Normality

The Shapiro-Wilk normality test was conducted to determine whether the pre-test and post-test data were normally distributed. The results indicated normal distribution for both tests ($p > .05$), allowing parametric tests to be applied.

4.3 Math Achievement Test (MAT)

The pre-test assessed participants' learning abilities and background knowledge for both groups, while the post-test measured learning ability after completing the intervention. Comparative analysis of pre-test and post-test means was conducted using box and whisker plots. Additionally, paired-sample t-tests were used to analyze within-group differences, and independent-sample t-tests were used to compare results between the Control and Experimental Groups. Both statistical tests used a significance level of .05.

4.4 Comparison of Pre-Test and Post-Test between The Groups

Figure 1 depicts the comparison of mean marks before and after the intervention in the CG. The median marks were 4 and 6 for the pre-test and post-test, respectively. The lowest marks were 2 and 1 in the pre-test and post-test, with maximum marks of 8 and 13 in the pre-test and post-test, respectively. The middle 50% of students scored between 3 and 6 in the pre-test and between 3 and 8 in the post-test. The mean marks were 4.61 in the pre-test and 5.87 in the post-test, indicating marginal improvement in mathematics performance in the CG.

Figure 2 shows the comparison of mean marks before and after the intervention in the EG. There

Figure 1. Box plot for pre-and post-test for CG.

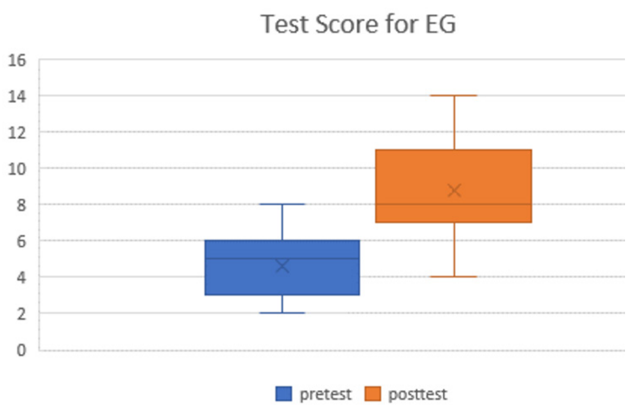

Figure 2. Box plots for pre-test and post-test for EG.

was a noticeable increase in mean marks after the intervention. The median marks were 5 and 8 for the pre-test and post-test, respectively. The lowest marks were 2 and 4 in the pre-test and post-test, with maximum marks of 8 and 14 in the pre-test and post-test, respectively. The middle 50% of students scored between 3 and 6 in the pre-test and between 7 and 11 in the post-test. The mean marks were 4.61 in the pre-test and 8.74 in the post-test, demonstrating significant improvement in mathematics performance in the EG following the games and simulations intervention.

4.5 Comparison of Pre-test and Post-post between the Groups

An independent-sample t-test was conducted at a 95% confidence interval to determine if there was a difference in mathematics learning between the CG and EG using games and simulations. In the pre-test, the CG (n = 31) scored an average of 4.55 (SD = 1.77), while the EG (n = 31) scored 4.61 (SD = 1.54). This difference was not statistically significant, t(30) = 1.83, p = .879, Cohen's d = 0.04, indicating no significant difference between groups before the intervention. However, in the post-test, the CG scored an average of 5.87 (SD = 3.06), while the EG scored 8.74 (SD = 2.86), with a statistically significant difference, t(30) = 6.23, p = .000, Cohen's d = 0.97, suggesting a medium effect size. Thus, the null hypothesis was rejected, indicating that the games and simulations intervention had a significant impact on the EG's mathematics achievement compared to the CG.

4.6 Comparison of Pre-test and Post-post within the Groups

A paired-sample t-test was conducted at a 95% confidence interval to compare pre-test and post-test scores within the CG and EG groups. The CG showed a non-significant improvement from pre-test (M = 4.55, SD = 1.77) to post-test (M = 4.61, SD = 1.31), t(30) = 1.83, p < .856. Conversely, the EG exhibited a significant improvement from pre-test (M = 4.61, SD = 2.87) to post-test (M = 8.74, SD = 1.54), t(30) = 6.23, p < .000, Cohen's

Table 3. Analysis of independent Sample T-test

MAT	CG		EG		t(28)	p	Cohen's d
	M	SD	M	SD			
Pretest	4.55	1.77	4.61	1.54	1.83	.879	
Post-test	5.87	3.06	8.74	2.86	6.23	.000	0.97

Cohen's d value: d=0.2-small effect, d=0.5-medium effect, d=0.8-large effect.

Table 4. Analysis of Paired Sample T-test

MAT	Pretest		Post-test		t(30)	p	Cohen's d
	M	SD	M	SD			
CG	4.55	1.77	4.61	2.87	1.83	.856	
EG	4.61	2.87	8.74	1.54	6.23	.000	1.82

Cohen's d value: d=0.2-small effect, d=0.5-medium effect, d=0.8-large effect.

Table 5. Overall Rating of Student's Perceptions of Games and Simulation in Teaching and Learning.

Statement	M	SD	Level of Perception	Further interpretation
The use of simulation and games makes me like mathematics.	4.42	.85	Very good	Positive
The use of simulations and games helps me to understand mathematics clearly.	4.52	.63	Very good	Positive
The use of simulations and games encourages me to take an active role in the activity.	4.29	.59	Very good	Positive
The use of simulation and games helps me build an in-depth understanding of mathematics.	4.26	.68	Very good	Positive
The use of simulation and games stimulates my interest in learning mathematics.	4.39	.56	Very good	Positive
The use of simulation and games encourages me to participate in the discussion.	4.03	.795	Very good	Positive
The use of simulation and games promotes effective group collaboration.	3.58	.81	Good	Positive
Motivates to learn mathematics when using simulation and games.	4.45	.62	Very good	Positive
By use of simulation and games in teaching mathematics, improves my problem-solving skills.	4.39	.56	Very good	Positive
The use of simulation and games enables mathematics in the real world.	3.84	.93	Good	Positive
Simulation and games help me to use procedures effectively and accurately.	3.81	.87	Good	Positive
The simulation and game develop confidence in mathematics	4.42	.56	Very good	Positive
The use of simulation and games fosters creativity and innovation in learning mathematics.	4.06	.81	Very good	Positive
Improve my arithmetic in mathematics by use of simulation and games.	4.19	.70	Very good	Positive
Problem-solving becomes efficient with the use of simulation and game.	4.03	.75	Very good	Positive
Overall Mean	4.18	0.71	Very good	Positive

d = 1.82.

4.7 Student's Perception of Games and Simulation in Teaching and Learning Mathematics

Table 5 presents students' perceptions of games and simulations in mathematics teaching and learning, showing an overall mean (M = 4.18) with a standard deviation (SD = 0.71), indicating positive opinions. Specifically, the statement 'The use of simulations and games helps me to understand mathematics clearly' received a high mean score (M = 4.52).

4.8 Correlation between Student's Perception and academic achievement

Pearson's correlation was performed to determine the relationship between student perceptions of games and simulation and academic performance. The correlation coefficient was interpreted using the Sugiyono (2013) rating scale as shown in Table 2. Table

Table 6. Correlation between Perception and Post-test score

Variables		Attitudes	Post-test
Attitudes	Pearson Correlation	1	.985**
	Sig. (2-tailed)		.000
Post-test	Pearson Correlation	.985**	1
	Sig. (2-tailed)	.000	

Correlation is significant at the level of 0.01

6 shows the correlation coefficient (r) of student perceptions of games and simulation $r = .985$ shows a strong degree of positive correlation between students' perceptions of games and simulation and respondents' post-test scores. In addition, the correlation between the two was found to be statistically significant ($r = .985$, $p < .001$) at a significance level ($\alpha = 5\%$).

4.9 Regression Analysis of Students' Perceptions and Test Scores on Learning Mathematics

A regression analysis was calculated to determine whether students' performance levels predicted the level of test scores. The result of the regression analysis (Table 7) shows that the relationship between the two variables was statistically significant, $\beta = 0.99$, $f(30) = 941$, $p < .05$. The model had an $R^2 = .97$, indicating that 97% of the variability in the students' mathematics achievement test was explained by students' perception of games and simulations in mathematics teaching and learning. The model produced a $\beta = .99$, indicating that for every one-point increase in students' perception of games and simulation elements, a 0.99 increase in MAT should be observed.

Table 7. Linear Regression Results on the Opinion of Games and Simulations and Post-test.

Independent variable	β	R2	df	F	P
Perception	.985	.970	30	941.15	.000

a. Dependent Variable: Post-test mark
b. Predictors: Attitudes

5. Discussion

The study examines the influence of simulations and games on the teaching and learning of mathematics and their impact on students' perceptions of these tools. In the study, polynomials were taught using games and simulations, specifically the quiz game, polyprod game, and PhET simulation.

5.1 The Effects of Games and Simulation on the Students' Mathematics Achievement

Pre-tests and post-tests were conducted with experimental and control groups of ninth-grade students. Initial comparative analysis of pre-test results did not reveal any differences in study performance between the experimental and control groups. The descriptive results of the pre-tests for both groups were similar. Additionally, inferential statistics such as independent sample t-tests and paired sample t-tests revealed no significant difference in achievement test results before interventions.

However, after a month of intervention, the post-test results showed a noticeable performance difference. The experimental group (EG) outperformed the control group (CG) in the achievement test, with a mean difference of 2.87. Inferential statistical results confirmed a significant difference in performance between the two groups post-intervention.

Consistent with Ke (2008), this study found that students exposed to mathematical games and simulations achieved higher scores. This alignment suggests that interactive learning tools can significantly enhance mathematics education.

Educators should consider integrating these tools to foster better engagement and understanding among students. Likewise, Taclay (2013) pointed out that the success of the EG was attributed to the interactive and engaging nature of game and simulation activities, allowing students to share ideas and enjoy the learning process. This finding implies that incorporating interactive and engaging game and simulation activities in mathematics education can enhance students' enjoyment and collaborative learning, potentially leading to improved academic achievement.

The findings of this study are also in line with previous research conducted by Navidad (2013), who reported significant improvement in motivation and academic achievement when teaching mathematics using student-designed games and simulations. Similarly, Taclay (2013) found higher performance scores in students exposed to math game strategy compared to those using traditional methods. Moreover, a study by Okechukwu et al. (2014) on quadratic expressions supported the superiority of mathematics games in enhancing student performance compared to traditional teaching methods.

Additionally, Lee (2009) reported improved understanding and performance in fractions through an educational game. The current study's results echoed these findings, indicating that the engagement, interactivity, and collaboration facilitated by games and simulations contributed to higher post-test performance in the experimental group. Thus, the study established that the use of mathematics games and simulations positively impacted student achievement and engagement, providing a more enjoyable and effective learning experience compared to traditional teaching methods.

5.2 Students' Perceptions towards Using Games and Simulations and its Relationship with Academic Achievement in Mathematics.

The findings confirm that students have positive perceptions towards the use of games and simulations in learning mathematics. The findings of the current study align with those of Cankaya and Karamete (2009), who substantiated a positive correlation between students who excel in math classes and those who hold favorable perceptions toward educational computer games and simulations. A similar study conducted by Ishaq et al. (2019) suggested that the simulation-games approach significantly enhances students' perception and achievement in mathematics. Moreover, students exposed to mathematical games and simulations enjoyed playing and solving mathematics problems, with the majority expressing a high level of enjoyment. Importantly, even students who were not good at mathematics found the activities enjoyable.

Additionally, the positive perceptions observed in the quantitative data may be attributed to the types of games and simulations used in the classroom. Concurrently, our findings are also in line with Can (2003), who conducted experimental studies indicating that participants had a positive view of educational computer games as valuable tools for instructional purposes. Moreover, this approach enhanced students' psychomotor, affective, and cognitive skills, fostering knowledge reconstruction through problem-solving in peer discussions (Ahmad & Latih, 2010). Furthermore, the incorporation of games in teaching and learning successfully made math feel less traditional, motivating many students to work harder due to the enjoyable and challenging nature of the activities (Lee, 2009).

The findings also suggest the effectiveness of games and simulations as teaching and learning tools. The findings are similar to those of Katmada et al. (2014), who found evidence in students' ability to facilitate experiential learning, provide alternative teaching methods, address mathematics phobias, and increase time on task. Additionally, the researchers indicated that by creating an adventurous and exploratory context, these tools challenged students to engage with and learn mathematics. Subsequently, reality-based scenarios and action-oriented game activities promoted meaningful interactions and constructive feedback, fostering collaborative knowledge construction (Cankaya & Karamete, 2009).

This perspective aligns with the views of educational theorists such as Prensky (2001), who emphasized the capacity of games to engage and motivate students. Similar findings were shared by Lee (2009), highlighting games as fun, engaging, motivating, interesting, and encouraging ways of teaching. Additionally, Katmada et al. (2014) investigated the impact of commercial math games and found positive results in students' perception of mathematics, motivation, and achievement. Overall, findings indicated positive perceptions of the use of games and simulations in mathematics classes, with evidence supporting their effectiveness in enhancing learning, motivation, and achievement.

6. Conclusions

The study aimed to examine the effectiveness of game and simulation approaches in teaching and learning mathematics in ninth-grade. The experimental group (EG) was taught using games and simulations, while the control group (CG) was taught using traditional methods. Both groups were evaluated with pre-tests and post-tests to assess significant differences in MAT scores. The recorded difference in mean scores between the EG and CG at the post-test indicated that students exposed to games and simulations performed significantly better than those in the traditional approach, demonstrating the greater impact of games and simulations on student performance in learning mathematics. Furthermore, respondents from the EG exhibited a positive perception towards the use of games and simulations in learning mathematics. Additionally, the study found a strong positive correlation between this positive opinion and academic performance. Moreover, simple linear regression analysis indicated that attitude was a significant predictor of performance in mathematics.

This study offers valuable insights into the effectiveness of using games and simulations in mathematics education. However, the findings are limited by the study's small sample size and short duration. Future research should explore these interventions over longer periods and with more diverse populations to confirm their efficacy. It enables readers to assess how this approach might be implemented in future classroom settings for mathematics learning. The findings suggest that games and simulations encourage student-centered learning, foster critical thinking, and promote creativity, linking mathematical concepts to the real world. Additionally, students become self-evaluators and receive instant feedback from digital games and simulations, leading to increased performance and interest in learning mathematics. Finally, based on the study's results, it can be inferred that the game and simulation approach has better potential for improving mathematics learning, performance, learning motivation, and student interest compared to the traditional approach.

7. Recommendations

To gain a deeper understanding of the effectiveness of games and simulations on student performance and perceptions, future studies can incorporate additional qualitative data collection tools such as interviews and classroom observations. This study can be replicated by including larger and broader samples to improve confidence in the results. Such studies could include samples from primary, secondary, and college levels across different classes. The intervention was conducted on only one chapter in one school over a duration of three weeks. Further research may extend the intervention period to draw more reliable and valid results.

References

Andale. (2014, October 20). Cronbach's Alpha: *Simple definition, use and interpretation. Retrieved on 7th June, 2023, from:* http://www.statisticshowto.com/cronbachs-alpha-spss/

Adamu, A. (2018). Gender differences in secondary school students' attitudes towards learning mathematics and the resulting implications on their performance. *Journal of Educational Research*, *6*(1), 179-192.

Ahmad, W., Shafie, A., & Latif, M. (2010). Role-playing game-based learning in mathematics. *Electronic Journal of Mathematics & Technology*, *4*(2), 184-196.

Barab, S. A., Gresalfi, M., & Ingram-Goble, A. (2010). Transformational play: Using games to position person, content, and context. *Educational Researcher*, *39*(7), 525-536.

Bausch, L., Beran, J., Cahanes, S., & Krug, L. (2008). Physiological responses while playing Nintendo Wii sports. *Journal of Undergraduate Kinesiology Research*, 3, 19-25.

Beaubien, J. M., & Baker, D. P. (2004). The use of simulation for training teamwork skills in health care: how low can you go? *Quality & Safety in Health Care*, 13(1), 51-6.

Bhutan Council for School Examinations and Assessment. (2019, 2020, 2021). *Pupil performance report*. Bhutan Council for School Examinations.

Becker, K. (2007). Pedagogy in commercial video games. Research and development frameworks (21-48).

Biddiss, E., & Irwin, J. (2010). Active video games to promote physical activity in children and youth. *Archives of Pediatrics and Adolescent Medicine,* 164, 664-672.

Bourgonjon, J., Valcke, M., Soetaert, R., & Schellens T. (2010). Student's perceptions about the use of video games in the classroom. *Computers & Education*, *54*(2), 1145-1156.

Burguillo, J. C. (2010). Using game theory and competition-based learning to stimulate student motivation and performance. *Computers and Education*, 55, 566-575.

Bustamante, A. S., Begolli, K. N., Alvarez-Vargas, D., Bailey, D. H., & Richland, L. E. (2022). Fraction ball: Playful and physically active fraction and decimal learning. *Journal of Educational Psychology, 114*(6), 1307-1320.

Can, G. (2003). Perceptions of prospective computer teachers toward the use of computer games with educational features in education, [Master of Science Thesis, The Middle East University].

Çankaya, S., & Karamete, A. (2009). The effects of educational computer games on students' attitudes towards mathematics course and educational computer games. *Procedia-Social and Behavioral Sciences*, *1*(1), 145-149.

Chernikova, O., Heitzmann, N., Stadler, M., Holzberger, D., Seidel, T., & Fischer, F. (2020). Simulation-based learning in higher education: A Meta-Analysis. *Review of Educational Research*, 90(4).

Cohen J. (1988). *Statistical power analysis for the behavioral sciences (2nd ed.).* Lawrence Erlbaum Associates.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education. Retrieved on 7th June, 2023, from:* http://knowledgeportal.pakteachers.org/sites/knowledgeportal.pakteachers.org/files/re sources/RESEARCH%20METHOD%20COHEN%20ok.pdf

Cook, D. A., Brydges, R., Zendejas, B., Hamstra, S. J., & Hatala, R. (2013). Technology enhanced simulation to assess health professionals: A systematic review of validity evidence, research methods, and reporting quality. *Academic Medicine, 88*(6), 872- 883.

Costu, S., Aydın S., & Filiz, M. (2009). Students' conceptions about browser-game-based learning in mathematics education: TTNetvitamin case. *Procedia-Social and Behavioral Science, 1*(1), 1848-1852.

Creswell, J. W. (2014). *Research Design.* Sage publication, Inc.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches.* Sage publication, Inc.

D'Angelo, C., Rutstein, D., Harris, C., Bernard, R., Borokhovski, E., & Haertel, G. (2014). Simulations for STEM learning: systematic review and meta-analysis. *SRI Education*.

Dolma, P. (2016). Investigating Bhutanese mathematics teachers' beliefs and practices in the context of curriculum reform. *Office of Education Research*, 1-259.

Hamalainen, R. (2008). Designing and evaluating collaboration in a virtual game environment for vocational learning. *Computers & Education*, 50, 98-109.

Heitzmann, N., Seidel, T., Opitz, A., Hetmanek, A., Wecker, C., Fischer, M., Ufer, S., Schmidmaier, R., Neuhaus, B., Siebeck, M., Stürmer, K., Obersteiner, A., Reiss, K., Girwidz, R., & Fischer, F. (2019). Facilitating diagnostic competences in simulations: A conceptual framework and a research agenda for medical and teacher education. *Frontline Learning Research*, 7(4), 1- 24.

Ishaq, A., Latunde, T., Ogwumu, D., Mustapha, A., & Ajinuhi, J. (2019). Impacts of Simulation-Games on Teaching} and Learning Mathematics. *Journal of Science Technology and Education*, *7*(4).

Jameel, H. T., & Ali, H. H. (2016). Causes of Poor Performance in Mathematics from Teachers, Parents and Student's Perspective. *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)*, *15*(1), 122- 136.

Kamii, C., & Rummelsburg, J. (2008). Arithmetic for first graders lacking number concepts. *Teaching Children Mathematics, 14*(7), 389- 394

Katmada, A., Mavridis, A., & Tsiatsos, T. (2014).

Implementing a game for supporting learning in mathematics. *Electronic Journal of E-Learning*, *12*(3), 230- 242.

Ke, F. (2008). Computer Games Application Within Alternative Classroom Goal Structures: Cognitive, Metacognitive, and Affective Evaluation. *Educ. Technol. Res. Devel.* (56), 539- 556.

Koskinen, Rauno. Pitkäniemi, Harri. (2022). Meaningful Learning in Mathematics: A Research Synthesis of Teaching Approaches. *International electronic journal of mathematics education, 17* (2).

Lee, Y. L. (2009). Enhancement of fractions from playing a game, Crossing divides: MERGA 32: *Proceedings of the 32nd Annual Conference of the Mathematics*, 1, 323- 330.

Liu, C. C., Cheng, Y. B., & Huang, C. W. (2011). The effect of simulation games on the learning of computational problem solving. *Computers & Education*, *57*(3), 1907- 1918.

Medical, BMC Education. (2016, September 16). How simulation in education benefits students and patients - university of St. Augustine for health sciences. https://www.usa.edu/blog/simulation-in-education/

Michel, H. (2016). Characterizing serious games implementation's strategies: Is higher education the new playground of serious games? Proceedings of the Annual Hawaii International Conference on System Sciences, 2016-March, 818- 826.

Millstone, J. (2012, October 13). National survey and video case studies: Teacher attitudes about digital games in the classroom. http://comminit.com/pioneers/content/national-survey-and-video-case-studies-teacher-attitudes-about-digital-games-classroom

Mohameda, S.H. & Tarmizi, R. A. (2010). Anxiety in mathematics learning among secondary school learners: A comparative study between Tanzania and Malaysia. *Procedia Social and Behavioral Sciences*, 8, 498- 504

Molenda, M., & Sullvian, M. (2003). *Issues and Trends in Instructional technology.* Educational media and Technology yearbook.

Navidad, F. (2013). Students' devised classroom games-simulations: An innovative tool on mathematics achievement and motivation in nursing students. *IPEDR, 60*(4), 14-18.

Okechukwu, A., Maduagwuna, N., & Ugama, J. O. (2014). Effect of mathematical game on students' achievement in quadratic expressions. *International Journal of Scientific & Engineering Research, 5*(6), 678-684.

Orlanda-Ventayen, C. C., & Ventayen, R. J. M. (2017). Role of social media in education: A teachers' perspective. *ASEAN Journal of Open and Distance Learning, 9*(2).

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and policy in mental health, 42*(5), 533–544.

Pareto, L., Arvemo, T., Dahl, Y., Haake, M. and Gulz, A. (2011) A teachable-agent arithmetic game's effects on mathematics understanding, attitude and self-efficacy, proceedings of the 15th International Conference on artificial intelligence in education, Auckland, New Zealand, Lecture Notes in Computer Science, 6738, 247-255.

Prensky, M. (2001, October 12). The digital game-based learning revolution. *Retrieved on 7th June, 2023, from:* http://www.marcprensky.com/.../prensky%20-%20ch1-digital%20game

Royal Education Council. (2009). *School Mathematics Curriculum Framework (PP – XII).* Ministry of Education.

Royal Education Council. (2021). *New Normal School Mathematics Curriculum Framework (PP – XII).* Ministry of Education.

Rogers, J., & Revesz, A. (2019). *The Routledge Handbook of Research Methods in Applied Linguistics*. Routledge.

Sauve, L., Renaud, L., Kaufman, D., & Marquis, J. S. (2007). Distinguishing between games and simulation: A systematic review. *Education Technology & Society*, *10*(3), 247–256.

Sedig, K. (2008). From play to thoughtful learning: A design strategy to engage children with mathematical representations. *Jl. of Computers in Mathematics and Science Teaching.*, 27(1), 65-101.

Taclay, R. J. (2013). Effects of mathematical games strategy on the achievement of students in high school geometry. *JPAIR Institutional Research*, 1, 85- 99.

Turner, R. & Carlson, L. (2003). Indexed of item-objective congruence for multidimensional items. *International Journal of Testing*, *3*(2), 163-172.

Sugiyono. (2013). *Metode Penelitian Pendidikan Pendekatan Kuantitatif, Kualitatif, dan R&D.* Bandung: Alfabeta.

Thomas, A. L. (2017). Digital game-based textbook vs. traditional print-based textbook: The effect of textbook format on college students' engagement with textbook content outside of the classroom. *The Turkish Online Journal of Educational Technology, 16*(4), 12-18.

Ünal, M. (2017). Preferences of teaching methods and techniques in mathematics with reasons. *Universal Journal of Educational Research, 5*(2) 194-202.

Utha, K., Giri, K., Gurung, B., Giri, N., Kjær-Rasmussen, L. K., Keller, H. D., Willert, S., Kurt Dauer Keller, K. D. (2016). *Quality of School Education in Bhutan: Case Studies in the Perspective of Gross National Happiness and Assessment Practices.* Aalborg Universitetsforlag.

Van Roessel, L., & van Mastrigt-Ide J. (2011). Collaboration and team composition in applied game creation processes. DiGRA 11, proceedings of DiGRA international conference, think design play, 1-14.

Vankúš, P. (2021). Influence of game-based learning in mathematics education on students' affective domain: A Systematic Review. *Mathematics*, *9*, 986.

Von Wangenheim, C. G., Savi, R., & Borgatto. (2012). A. F. DELIVER! – An educational game for teaching earned value management in computing courses. *Information and Software Technology*. (54) 286–298.

Vlachopoulos, D., & Makri, A. (2017). The effect of games and simulations on higher education: a systematic literature review. *International Journal of Educational Technology in Higher Education*, *14*(1), 1- 33.

Willoughby, T. (2008). A short-term longitudinal study of internet and computer game use by adolescent boys and girls: Prevalence, frequency of use, and psychosocial predictors. *Developmental Psychology, 44*(1), 195- 204.

Yang, J. C., Chien, K. H., & Liu, T. C. (2012). A digital game-based learning system energy for energy education: An energy conservation pet. *The Turkish Online Journal of Educational Technology, 11*(2), 27-37.

Yue, W., & Zin, N. (2009). *History educational games design.* Institute of Electrical and Electronics Engineers (IEEE).

Zarraonandia, T., Díaz, P., & Aedo, I. (2022). Engaging educators in the ideation of scenarios for cross-reality game-based learning experiences. *Multimed Tools Appl*.