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PAPER

The Effect of Virtual Reality Technology in Teaching Mathematics on Students' Ability to Process Data and Graphic Representation

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ABSTRACT

The study focused on the impact of using augmented reality (AR) in teaching mathematics to tenth-grade students in the 2022–2023 academic year. The sample consisted of 70 students from schools in the city of Amman, who were divided into 35 students in the experimental group and 35 students in the control group. The researcher utilized the quasi-experimental method and collected data through questionnaires and testing tools. Data were statistically analyzed using the MANOVA test, outcome analysis techniques, and GLM test. The results indicate the quality of virtual reality (VR). Students' ability to process data improved by 94% in the experimental group and 88% in the control group. The experimental group demonstrated an effective contribution of 97% in improving graphic representation ability, while the control group showed a contribution of 92%. The study relied on the descriptive-analytical method. The study concluded that AR technology and its usage have become largely dependent on preparing technical and material requirements. It also highlighted that this technology aids students in learning scientific facts, concepts, and instructions in an easy and effective manner. The results indicate the necessity of expanding scientific research and studies on the advantages and disadvantages of AR technology and its optimal utilization.

KEYWORDS

virtual reality (VR) technology, teaching mathematics, process data, graphic representation

1 INTRODUCTION

1.1 Virtual reality

Virtual reality (VR) is a new technology for creating an immersive environment that simulates real-life surroundings [1]. VR technology immerses the user in an experience rather than merely observing a screen in front of them. Users can interact with a 3-dimensional world using multiple senses, including sight and even touch,

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facilitated by wearing VR glasses [2]. By utilizing VR technology in science education, students can explore various scientific topics in a fun and interactive manner, including space, the solar system, human anatomy, and other scientific fields [3]. VR technology can also be used to enhance the display of scientific experiments. This allows students to explore and interact with experiments safely and flexibly, without the need for dangerous or expensive equipment [4].

Virtual reality technology relies on the display technology with one of the most notable components being is the headset. This device enables users to experience VR visually through advanced display technologies and immerse themselves in the virtual environment with the latest audio technologies that provide realistic sound effects. One of the most well-known devices for this purpose is VR glasses. The default options include HTC Vivi Pro Eye, Oculus, and PS VR, but there are also products available from Google, Apple, Samsung, Lenovo, and other companies [5].

Augmented reality (AR) has transformed the concepts of mathematics by utilizing 3D models to present the subject. This innovation has made it possible to elucidate challenging and intricate concepts in a simplified and enjoyable manner for students. It also enables you to display geometric shapes in distinctive ways and explain angles and geometric dimensions more accurately, which enhances the information in the minds of students [6]. AR technologies provide the possibility of interaction and participation between students and teachers within the classroom. They also offer teachers the convenience of explaining educational material and helping students retain information more effectively [7].

By relying on modern technologies in education, schools and institutions can advance in simple and efficient ways. The increasing demand for these technologies is due to their utilization of modern technical methods to explain and teach academic subjects effectively. This encourages students and parents to adopt them in schools to set themselves apart from others [8].

The use of AR technology in mathematics helps students solve complex equations and enables remote explanation, making the subject more accessible even in the absence of a teacher [9]. The application enables teachers to easily enhance the explanation of abstract information and symbols to students. It also allows for the presentation of mathematical information through 3D models, making the material clearer and reducing the cost of educational publications [10].

Virtual media represent tangible media in cognitive and technical artifacts that are dynamic virtual forms. They can be manipulated by moving, rotating, and transforming them, similar to how one would interact with a 3D tangible object [13].

Virtual methods, such as anthropomorphic methods, offer students the same capability to comprehend processes and observe relationships between them [14]. Virtual media are tools that enable students to explore mathematical concepts through interaction with applications. Since most applications can be accessed online, they are less expensive than physical tools [15].

Many virtual tools have embedded learning sequences that help build meaning and clarity in mathematical concepts as students interact with the resource [16]. An additional advantage of virtual “digital” media is the ability to modify the shape of the figure displayed on the screen or add mathematical symbols to the figure [17–18]. Students who suffer from psychological and motor difficulties and are unable to deal effectively with small characters may benefit from using the computer as a learning resource. The computer can help them perform well by drawing attention and maintaining engagement. In addition, some students who suffer from behavioral problems find it beneficial to engage and integrate into the lesson without distracting other students [19–21].

1.2 Virtual reality in mathematics learning

Today's classrooms do not provide enough time for teachers to meet the challenging task of preparing students for the future's demands. Utilizing VR to learn mathematics via the ORYX educational platform assists students and teachers in overcoming these challenges by providing an interactive, research-based learning environment. ORYX Education believes that the developments of life in our time require us to be constant learners. Therefore, it was necessary from the beginning to help students develop higher-order thinking and self-learning skills to ensure a brighter future.

Through its carefully designed interactive mathematics curriculum, ORYX Education assists students and teachers by:

- Providing hundreds of fun and advanced activities to engage students interactively.
- Providing examples, solutions, explanations, and videos in the simplest forms.
- Providing advanced professional educational videos with engaging content.
- Providing fun and engaging content to facilitate the development of higher-order thinking skills.
- Providing advanced educational videos to support teachers in the educational process.
- Teaching concepts aimed at achieving mastery.
- Providing distance learning when schools are closed to help students continue making progress.

ORYX Analytics displays students' overall performance, strengths, skills, and areas that require remediation. Through ORYX analytics, the teacher assigns suitable and essential lessons to each student individually. The analyses show the student's level in detail and what they must do to achieve success. This mechanism helps students reach the highest levels.

ORYX content is designed by experienced professional teachers and aligned with nationally recognized mathematics standards. Therefore, teachers and parents need to ensure that students develop higher-order thinking skills so that they can solve difficult problems and work collaboratively toward a better future [17]. Here are some examples of virtual tools that can enhance mathematical learning:

- Algebra squares are mathematical tools that enable students to better understand algebraic definitions and teach how to apply and solve algebraic problems. They use algebra squares to represent variables and constants in equations, replace the symbols of variables with constant values, and follow the steps to arrive at a solution. Through this method, algebra students can add squares, remove placeholders or zeros, and represent equations for review and experimentation [18].
- Applying integer tiles is a method that helps students gain a better understanding and simplifies the teaching of positive and negative integers. It represents the process of addition and subtraction between integers, whether negative or positive. The student can represent the integers (positive and negative) encountered in problems using the slide tool provided. In Oryx Education, students can represent positive numbers with one color and negative numbers with a different color to gather information and conduct experiments [23].
- "Representing Fractions" utilizes fraction models, whether rectangular or circular, to assist students in comprehending the concept that fractions represent parts of a whole, explaining the concepts of comparing and simplifying fractions, finding equivalent fractions up to 100, and ultimately validating the solution.

When it comes to solving fractions using the circular model, the focus is on understanding the relationship between the part and the whole. The student estimates the fraction that the part represents in relation to the whole. On the other hand, the rectangular model for solving fractions is considered simpler as it allows the student to draw more accurately. Use the first slider to adjust the total parts of the model and the second slider to adjust the number of shaded parts to observe how the models can be modified [13].

- Utilize the interactive coordinate plane tool to plot coordinates and represent them in one, two, or all four quadrants. You can also learn about gender transformations and understand various concepts and algebraic operations of knowledge and experience [6].
- Applying the rule of ten cubes helps students learn basic mathematical concepts such as addition, subtraction, recognizing numbers, place value, and counting. All these basic concepts are simplified using a very engaging method known as the rule of ten cubes. These cubes can be used in various ways to represent numbers, patterns, and addition and subtraction operations [6].
- Applying the number line rule helps students understand the sequence of numbers and explains the various ways to utilize them, including counting, comparing, adding, subtracting, multiplying, and dividing. Use the interactive number line with integers, fractions, or decimals to practice mathematical operations for learning and experimentation [18].
- Methods for teaching probability. Probability is a method used in mathematics to calculate the number of possibilities resulting from placing elements in groups and then finding the probability ratio based on the arrangement of the group elements and identifying similarities [20].

The ORYX interactive learning platform provides guided exploration opportunities for students, helps them develop an understanding of mathematical concepts, demonstrate their cognitive abilities, and share their achievements with family and school. Utilizing ORYX educational methods and tools can help explain and clarify misconceptions, as well as strengthen the relationship between concepts and their practical application on the ground [22–25].

Real-life applications enable students to explore solids and shapes realistically and interactively, fostering engagement and deep understanding. Using VR to learn mathematics on the ORYX educational platform is a specialized educational resource that aims to develop educational technologies to create an enjoyable learning experience. It provides exercises, level assessments, explanation tools, and enrichment resources for teachers. Additionally, it offers clear explanations to assist learners during the self-learning process.

1.3 Related work

The study [1] of the reality of using modern technologies and methods in teaching science curricula in general education, as perceived by science teachers, revealed that the data display device was the most commonly utilized tool, followed by the computer.

The study [3] showed that mathematics teachers have a tendency to integrate ICT in the classroom, and the results were positive.

The results of the study [5] showed that more than seventy percent of the participating teachers in Haifa had positive perceptions about integrating and using

technology in education, despite their lack of the necessary knowledge to deal with those technologies.

The study [9] focused on the benefits and challenges that teachers face when integrating technology into the mathematics teaching process in 28 secondary schools in Malaysia. The results of the study concluded that teachers were able to use their laptops with ICT accessories.

The study [6] aimed to identify the obstacles that prevent teachers from using computers and the Internet in teaching mathematics. The results showed that the most important obstacles were the lack of display devices and the absence of a suitable place to use the computer.

The study [7] focused on the use of ICT in Wessels Secondary School for teaching and learning mathematics. It developed strategies for incorporating ICT in the teaching and learning of mathematics for similar rural schools like Wessels Secondary School.

The study [8] aimed to investigate how high school mathematics teachers in California use computer technologies and calculators in their classrooms. One of the most important results of the study is that mathematics teachers are urgently in need of training in educational software technology. The researcher recommended working to overcome the obstacles that hinder the integration of computer technology in teaching mathematics.

The study [11] investigated the possibility of integrating technology into mathematics to implement mathematical operations. The research revealed that technology can be integrated into mathematics to implement mathematical operations. It can also assist students in collecting, analyzing, and presenting information to construct or utilize a specific model. Trends in VR studies indicate that most research focuses on educational achievement, motivation, and attitudes, highlighting a scarcity of qualitative research in this field [7]. Most research compares student learning outcomes when using VR to other methods, such as traditional education. Research indicates that VR is more effective for visual educational content, while AR is a better option for auditory learning [11]. The research did not find any significant differences in learning outcomes between VR, AR, and practical experiences [8]. The study [9] found that cooperative learning in VR environments leads to greater learning gains compared to traditional methods in science.

The study aimed to determine the impact of VR technology on teaching mathematics and its effect on tenth-grade students' ability to process data and understand graphic representations for the academic year 2022–2023.

1.4 The study problem

Education in the Kingdom of Jordan is a top priority for the Ministry of Education, which strives to stay abreast of the latest technological advancements. The ministry integrates technology into the educational process and utilizes communication and information technology to enhance the quality of education. Mathematics curricula have also witnessed development at all educational levels. Consequently, there is a growing need to incorporate modern methods and techniques into teaching mathematics at the elementary level. AR technology is one of the tools that assists mathematics teachers in explaining and conveying information to students in a simplified and clearer manner. From this standpoint, the Ministry of Education has made great efforts to develop methods for teaching mathematics and has emphasized the use of modern technologies in its instruction. Despite the efforts and continuous development of science curricula in the Kingdom of Jordan, recent results

from international tests (TIMSS) have shown that students achieve low scores. Based on the above information and a review of experiences and literature, the problem of the study can be defined by the following questions:

- Is there an impact of VR technology in teaching mathematics on students' ability to process data and graphic representation for tenth-grade students for the year 2022–2023?
- Are there statistically significant differences between using VR technology in teaching mathematics and students' ability to process data and graphic representation among tenth-grade students in the years 2022–2023?

1.5 Study importance

The importance of the study stems from:

- The importance of students lies at the core of the educational and learning process, followed by the significance of teaching, preparing, and training them. This necessitates research and exploration to identify the most effective educational and learning systems and applications that can enhance student achievement and equip community institutions with competent personnel.
- Keeping up with scientific progress and the flow of information for most effective to educational systems to save time and effort.
- E-learning and its technologies, such as the use of AR, are considered safer and more secure than traditional education, especially when conducting dangerous and challenging experiments in physical laboratories. It is expected to achieve proficient teaching and learning through a high degree of cooperation among learners. The effectiveness of VR relies on the utilization of electronic multimedia for communication, information reception, and skill acquisition.

2 METHODOLOGY

2.1 Design and research subject

The research sample consisted of 70 tenth-grade students for the academic year 2022–2023 in the city of Amman, Jordan. Experimental group A consisted of 35 tenth-grade students who used VR, while control group B consisted of 35 tenth-grade students who used the traditional method.

2.2 Research procedure

Application of VR to the experimental group A of tenth-grade mathematics students in the data representation unit of the mathematics subject. The control group (B) received traditional teaching in the same unit. Two tests (pre-test and post-test) were conducted to measure the students' ability to handle data and graphical representation. The test was designed to consist of eight questions, some of which measure the students' ability to deal with data, while the other four measure graphical representation. It was presented to three experts: an education expert, a mathematics expert, and an information technology expert (refer to Table 1).

Table 1. Indicator of students' abilities in dealing with data and graphical representation

Research Variable	Indicator	Question Indicator	Item Number
Data	The student identifies and collects data	The student identifies and collects data	1
	The student's ability to analyze data	Students analyze the data provided (simple calculations, identifying patterns)	2
	The student's ability to interpret data	Processes data	3
	The student's ability to implement data	The student applies the results of data analysis to a real-life situation	4
Graphic Representation	The student's ability to represent data in graphs	The student represents data from graphics (bar charts, line charts, pie charts)	5
	The student's ability to interpret the relationship between variables in graphs	Students interpret relationships in graphs between variables (identify trends, comparisons, correlations)	6
	The student's ability to conduct extrapolation and predictions	The student extrapolates and predicts using graphs	7
	Problem-Solving	Student solves problems and answers questions Students can using a graph	8

2.3 Data collection instruments

Data were collected through the teacher's observation records of students, direct interviews with students, and a questionnaire. The researcher chose to rely on the questionnaire as a data collection tool for this study because it was suitable for the nature of the study. The researcher developed a questionnaire for the students based on the study's problem and goal. After reviewing the literature on the use of VR technology in teaching mathematics and considering the study's questions and objectives, the questionnaire was divided into three sections:

- The availability of devices and tools in the classroom and school environment is necessary for using VR technology in mathematics lessons.
- The extent to which VR technology is used in teaching mathematics.
- Obstacles that hinder the use of VR technology in teaching mathematics.

To ensure the validity and reliability of the research tool, the questionnaire was reviewed by experienced educators specializing in teaching methods to evaluate the clarity of expressions and linguistic integrity. The stability of the questionnaire was assessed using Cronbach's alpha equation on the study sample's questionnaires. The reliability coefficient reached a generally acceptable level of statistical stability (alpha, $\alpha = 0.80$), indicating a high degree of stability and trustworthiness for current research applications.

In addition to the questionnaire, a pre-test and post-test were conducted to measure students' ability to handle data and create graphs. By combining these data collection techniques with qualitative data (observations, interviews, and questionnaires), the researcher gained a comprehensive understanding of students' abilities to represent data through graphs. The questionnaire was analyzed using a scoring

method ranging from 1 to 4. The percentage was calculated using the formula: (number of student responses)/(total scores) × 100%, as shown in Table 2.

Table 2. Scores of students' answers to the questionnaire

No	Interval (%)	Category
1	76–100	Strongly Agree
2	56–75	Agree
3	40–55	Not agree
4	0–39	Strongly Disagree

2.4 Analysis of test data

The scores of the pre- and post-tests administered to the students in the study sample were analyzed. The equation used is: Score = (score obtained)/(maximum score) × 100%. To calculate the test result, we analyzed the extent to which students' graphic representation abilities improved based on the pre- and post-test scores using the following equation [12]: Improvement = (post-test score – pre-test score)/(100 – pre-test score) (Refer to Table 3).

Table 3. Criteria for evaluating student improvement

No	Value	Criteria
1	$g \geq 0.70$	High
2	$0.30 \leq g < 0.70$	Moderate
3	$g < 0.30$	Low

Conducting a MANOVA test after the researcher has completed all tests. A one-way ANOVA test was conducted to prepare the data for testing specific differences.

3 RESULTS

Students' responses to the questionnaire about the use of VR are presented in Table 4.

Table 4. Students' responses to the questionnaire about the use of VR

No	Rated Aspect	Score	Category
1	Ease of Use	3.2	Very Good
2	Benefits	3.0	Very Good
3	Appeal	3.0	Very Good
4	Attractiveness	3.2	Very Good
Average		**3.1**	**Very Good**

The results indicate an improvement in data processing, suggesting that the use of VR is effective (refer to Table 5).

Table 5. Result of Test the ability to process data

No	Class	Number of Students	Average the Ability to Process Data		Average Gain	Category
			Pretest	Posttest		
1	Experiment	36	32.86	81.00	0.73	High
2	Control	34	33.06	70.32	0.57	Moderate

The results indicate that students' abilities to represent graphically have improved, suggesting that the use of VR is effective (refer to Table 6).

Table 6. The result of testing the student's ability to perform graphic representation

No	Class	Number of Students	Average Ability to Perform Graphic Representation		Average Gain	Category
			Pretest	Posttest		
1	Experiment	36	20.39	78.50	0.74	High
2	Control	34	20.12	65.58	0.58	Moderate

A test for matrix homogeneity was performed for the variables in the M square, resulting in a significance value (sig = 0.902). Since sig > 0.05, this indicates the presence of homogeneity (refer to Table 7).

Table 7. Result matrix homogeneity

Box's Test of Equality of Covariance Matrices	
Box M	0.683
F	0.220
df1	3.000
df2	900007.400
Sig.	0.902

The statistical hypotheses were as follows:

- H: ($\mu i = \mu j$) There is no difference between students who used VR and those who did not use virtual reality.
- H0: ($\mu i \neq \mu j$) There is a difference between students who used VR (A) and those who did not use VR (B). The significance value (sig) of the multivariate test was found to be 0.000, which is less than 0.05.

This indicates a significant difference between those who used VR and the students who did not use VR, see Table 8.

Table 8. Result of multivariate tests

Effect	Group	Value	F	Hypothesis df	Error df	Sig.
Model	A	.249	11.125	2.000	67.000	.000
	B	.751	11.125	2.000	67.000	.000

Effect tests were conducted between the treatment and control groups. The significance value (sig) of the multivariate test was found to be 0.000, which is less than 0.05. This indicates that there is a significant difference in data capabilities and graphical representation capabilities. H0 was rejected based on the analysis conducted to test the hypotheses, indicating a significant difference between the students who utilized VR and those who did not use VR (refer to Table 9).

Table 9. Tests of between-subjects effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	Data	1881.0	1	1881.0	14.00	.000
	Graphic	2731.5	1	2731.5	19.162	.000

Using the general linear model (GLM), the experimental group contributed 94% and the control group contributed 88% to the improvement of data processing ability. The experimental group demonstrated an effective contribution of 97% to improving graphic representation ability, while the control group showed a contribution of 92%. This shows that the experimental group was more effective compared to the control group, as presented in Table 10.

Table 10. Multivariate trace test

Variable	Treatment Class	F	Sig.	Partial Eta Squared
Data	Experiment	981.13	0.000	0.94
	Control	551.00	0.000	0.88
Graphic	Experiment	2016.474	0.000	0.97
	Control	1180.341	0.000	0.92

4 DISCUSSION

Results related to the first question and its text: What is the impact of applying VR on academic achievement in mathematics among tenth-grade students in Amman? The result indicates the effectiveness of this strategy and its direct, positive impact on understanding mathematics, leading to higher scores in academic achievement. This is consistent with the results of the previous study [11]. This result was obtained using MANOVA, where the significance value was (sig = 0.00), which is less than 0.05. This indicates a significant difference between students who used VR and those who did not. This indicates that the use of VR is effective, which is consistent with the results of the previous study [6]. The results also indicated that there were statistically significant differences at the level of ($0.05 \geq \alpha$) in the sample members' estimates due to the use of AR, which is consistent with the findings of the previous study [7]. This indicates a significant improvement in data processing and graphical representation among students who used AR (experimental group A) compared to students who did not use VR (control group B), and this is consistent with the results of the previous study [2]. This confirms the necessity of adopting this strategy

and activating its role to raise the educational level of elementary school students. The researcher recommends the following:

- Adopting the strategy of using VR in schools to teach mathematics.
- Holding training and guidance courses on utilizing VR in teaching mathematics.
- Drawing attention to the role of using VR in teaching mathematics for universities and the Department of Educational Sciences.

5 CONCLUSIONS

The study indicates that using VR technology in teaching mathematics can help students achieve better results, improve the level of interaction and participation, and represent a significant opportunity to enhance the learning experience for students. Despite the benefits of using VR technology in education, there are challenges that may hinder the future adoption of this technology. These challenges include cost, availability of infrastructure, teacher capacity, social displacement, security, and privacy. In general, the utilization of VR technology in education may encounter challenges in the future. Schools and educational institutions must strategize on how to effectively address these challenges to maximize the potential of these devices in enriching the learning experience. By utilizing VR technology in mathematics education, schools and educational institutions can enhance the quality of education, improve understanding, and facilitate interaction with scientific materials. VR technology enables students to immerse themselves in an interactive and realistic virtual environment, aiding in their comprehension of scientific concepts and their practical application. There are many studies [1], [3], [7–9], [11] that have proven the effectiveness of using VR technology in teaching mathematics. Students can achieve better results in their studies, interact more effectively, and participate more actively. Employing virtual and AR in the educational process aims to assist learners in comprehending and managing information more effectively. It also offers diverse methods to present information dynamically and visually, thereby enhancing academic achievement. The significance of the results of this study lies in addressing the impact of implementing AR programs on the academic performance of tenth-grade students in mathematics. Therefore, its importance is determined by two aspects:

1. Theoretical importance: This study provides a theoretical review of key variables in the field of education, specifically focusing on teaching methods utilizing VR. Through this study, the researcher aims to enhance teachers' motivation to utilize modern technology and AR programs in mathematics.
2. Practical importance:
   - This study can benefit all parties involved in developing teaching methods in educational institutions.
   - The results of the study can be utilized to enhance teaching for students and boost their academic performance.

   This study can also be used to implement AR programs for various age groups.

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