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PAPER

The Impact of Artificial Intelligence-Based Virtual Laboratories on Developing Students' Motivation Towards Learning Mathematics

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ABSTRACT

This research investigates the impact of virtual laboratories (VLabs) based on artificial intelligence (AI) on developing students' motivation toward learning mathematics. A semi-experimental approach is used to achieve the research objectives. The research sample, consisting of 80students from the seventh grade, is selected by the purposeful sampling approach. The research sample is randomly distributed into three groups: two experimental groups and one control group. The first group of 26 students is taught using the AI-based VLabs, while the second group of 27 students is taught using a VLab based on 3D visual imaging, and the third group, a control group consisting of 27 students, is taught using the traditional approach. The research instrument, a questionnaire for learning motivation, was designed after ensuring its validity and reliability. The findings of the motivation questionnaire indicate that students in the first experimental group have more motivation to learn mathematics than students in the second experimental group and the control group. The results also show that the students in the second experimental group have more motivation to learn mathematics than the students in the control group. Given the said findings, the research recommends using virtual laboratories based on artificial intelligence and all its applications in the learning process due to their impact on students' mathematics learning.

KEYWORDS

artificial intelligence (AI), virtual laboratories (VLabs), motivation

1 INTRODUCTION

The world has recently witnessed a huge development in technical technology in all sectors due to rapid cognitive development, which has brought about several changes. This technology-based development has imposed itself on the nature of life in which we live to automatically change the course of life fields, including education,

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which is a fundamental part of the fabric of modern life. Hence, the educational system must keep pace with these rapid changes by incorporating technology into education, as it is the most significant criterion for the success of the educational process. Technological reality seems to have a positive impact on the educational process, making it an inspiring learning environment that simulates science fiction and the virtual world through scientific laboratories based on artificial intelligence.

Various companies have taken advantage of information technology (IT) applications such as Google, Facebook, Yenka, Crocodile Clips, automatic translation and research tasks, and prediction of the ideas of users of webpages, websites, and many other companies, thus launching many programs to serve education [12], [17], [27]. Great interest in the use of artificial intelligence is evident in education and the shift to individual learning and distance learning. Research, studies, and national and international conferences, alongside researchers [19], reveal the extent of benefits achieved from artificial intelligence applications in learning, especially learning abstract sciences and conducting dangerous and financially expensive scientific experiments.

[16] refers to the International Conference on Artificial Intelligence and Education held in China in 2021, emphasizing the need to include smart applications and modern technologies in the educational path as it achieves the transfer of the quality of education to a high level. These conferences have also proposed a set of software, supportive applications for schools and students, and educational services that take into account the individual differences of students and achieve equality among them in acquiring knowledge and learning by providing education to teachers and learners according to their individual needs and differences.

At the same level, interactive virtual learning environments based on artificial intelligence are the most available environments with abundant information that provide students with opportunities to interact and look at what is abstract and difficult to learn and embody in reality. [32] confirm that virtual learning environments contribute to the survival of the impact of learning among students in all scientific subjects, especially in the field of chemistry, for it depends for the most part on chemical reactions difficult to apply as a result of public safety, cost, risk, and the lack of laboratories necessary to conduct them, which reflects on students with low achievement and ability to learn.

Virtual laboratories are part of virtual reality to increase students' eagerness to learn and improve their motivation. Furthermore, artificial intelligence applications increase the interaction between the learner and the content, such as the Catboat application. For example, when teachers leave room for the student to practice various applications and their representations in mathematics in all its forms, this will be one of the greatest incentives and motivations for them to learn. By introducing the concepts of artificial intelligence-based virtual laboratories for developing students' learning processes, the related literature review is provided in the next section.

2 LITERATURE REVIEW

Virtual learning is now an inevitable necessity in the era of digitization. Interest and demand in countries around the world have recently increased for so-called virtual learning, as many educational institutions offer courses for education via the Internet as an alternative to regular courses. Various educational studies, including [12], [30], agree on the importance and effectiveness of virtual learning in the educational learning process via the Internet through many advanced learning instruments.

Virtual learning achieves self-learning, and educational endeavors are achieved towards individualizing education, where the students can learn according to their abilities, desires, speed in education, and willingness to rely on their previous knowledge, as the educational content in this approach is presented in the best method to improve performance and results. [31] adds that virtual learning integrates technology into the educational field to enhance the learning process and the relationship between content, learning methods, and strategies that develop students' motivation towards learning to achieve interaction in the education process.

Likewise, [4] indicates that virtual learning has been a remarkable innovation in the history of education, as it is a learning alternative that helps to change traditional learning contexts thanks to the benefits and support for learning capabilities, especially when incorporating e-learning with its appropriate virtual simulation applications to embody reality. Virtual education is characterized by characteristics that depend in a way on the students themselves and their ability to conduct research through their efforts rather than relying on the teacher. [4] adds that one of the deeply established characteristics that make virtual learning a turning point for digital learning is that it contributes to increasing learning opportunities for everyone and in all circumstances, thus producing self-learning and raising the student's desire for information.

[11] and [19] also indicate the effectiveness of three-dimensional virtual learning environments in teaching physics at the secondary level on students' achievement and their attitudes toward learning. One of the latest technological innovations regarded as an extension of the electronic simulation system is the visualization of real laboratories and the results of their experiments. [35] state that VLabs are a kind of virtual reality, as they are a simulation of a real science laboratory to conduct chemical, physical, biological, earth sciences, and mathematics applications by linking the practical side with the theoretical side and developing thinking skills without the negative impact of any possible risks facing the learner. They are also digital scientific laboratories with high working speeds, high storage capacities, computer-based software, and connections to the global network.

[29] refers to the simulation of programmed laboratories as the fact that it enables the student to conduct experiments remotely more than once, compensates for the absence of laboratory equipment and materials, and covers virtually most of the ideas and experiments in the course, which is difficult to achieve within the reality of the number of laboratories and their equipment available. VLabs help ensure interactive learning and students' active participation while learning. They are realistic simulations of traditional science laboratories in schools, in which the students feel as if they are in a real laboratory that has all the capabilities and tools that they use to conduct experiments.

Virtual laboratory can be used to conduct experiments that are difficult to implement due to economic costs, and spatial and time limitations [20]. The virtual laboratory provides the possibility of conducting laboratory experiments difficult to implement in real laboratories due to their danger to the learner at all times, such as nuclear energy and other experiments whose data cannot be visualized. This is confirmed by [10]. The use of the VLab facilitates the process of conducting difficult, long, complex, and expensive experiments, including some that are impossible to perform in regular laboratories.

Studies have demonstrated the effectiveness of VLabs in the learning process, particularly in mathematics, which ensures learner interaction, especially in practical experiments that are difficult to implement, confirming that scientific materials are closely related to technological innovations [9], [11], [13], [23], [24], [29].

2.1 Laboratories based on 3D imaging 360 degrees with 3D technology

They are VLabs based on real experiments that use video cameras and integrate into the program to be presented to the student by transmitting a video image of the development of the real experiment. They are laboratories that do not rely on artificial intelligence, as they only visualize reality with 3D technology and transfer it as it is to display what is happening in reality. However, it is difficult to visualize due to the difficulty of viewing it with the naked eye, the difficulty or danger of forming its conditions, or the high cost of its materials, so it is difficult to repeat it in front of the students as much as possible.

2.2 The laboratories based on artificial intelligence

The laboratories based on AI are classified as follows:

- **Two-dimensional virtual laboratories.** They rely on the software installed on the computer based on mathematical models and equations to show applications and representations of many mathematical concepts, thus meeting previous experiences and ignoring everything that is in the real laboratory.
- **Three-dimensional virtual laboratories.** They are a two-dimensional development and are based on software on the computer with higher techniques for graphics, images, sound, and animations for various mathematical concepts. The student interacts with them, touches the reactions to the experiments, and watches the changes in these interactions.
- **Remote virtual laboratories.** They are remotely controlled via the network by the student. In turn, the computer controls the devices used in the experiment to measure, produce heat or electricity, and watch the results through a video broadcast.

Virtual laboratories are classified based on their purpose, working methodology, and the experiments they facilitate. Procedural laboratories are designed to enable students to work on challenging, dangerous, rare, and costly scientific experiments by utilizing virtual materials and equipment in a safe and cost-effective environment [25]. Exploratory laboratories are useful for learning to attain new results through multiple experiments and provide an opportunity for students to repeat experiments, leading to new scientific investigations.

2.3 Virtual laboratories challenges

Plenty of obstacles limit the tendency to use VLabs in the learning process, despite their significance and role in improving the general level of the elements of the process. Among these obstacles are the lack of technical infrastructure and software, weak interaction between teachers and students, and the low level of use of VLab software by students and teachers. [28] emphasize another set of obstacles, such as weaknesses in professionally and entertainingly designing VLab programs that attract students and the lack of experts in the field of producing virtual laboratory programs for local curricula.

[5] mentions other obstacles to the use of the VLab, such as its confusing nature to a large extent for students who do not know how to use the computer, errors and

technical problems related to the software of the virtual or computer-related labs, as well as the resistance to changing the teaching style that may appear among some teachers and students. Despite the fun and suspense of performing experiments virtually, some requirements must be met. [26] confirms that there are requirements represented in the provision of devices and equipment with special specifications that are not available to all learners and teachers competent in the English language because few of them support the Arabic language. In addition, working on these devices and equipment requires training and high technical skills on the part of the teacher and students. [6] stresses the necessity of working on providing computer software related to mathematics courses, training teachers to employ VLabs in teaching mathematics, and benefiting from teachers with experience in teaching and employing VLabs.

2.4 Experiments with 360-degree imaging technology in 3D

These experiments are learning videos explaining the use of the laboratory, equipment, and procedures for experiments with high-tech professional 360-degree imaging in 3D [7]. Learning videos are increasingly being used as supplementary educational resources for mathematics and other applicable subjects. Educational videos are displayed in a saved video or through websites in two ways: by navigating the video by moving horizontally and vertically, or by clicking on it and navigating as it applies to Google Street View.

It is worth noting that teaching and using video has been part of education for a previous period, especially in medical education, as students use it to study the reasons and procedures for their assignments related to their studies, especially in medical operations. Teaching and using video has led to a reduction in study time, an increase in student performance compared to those who read their subjects theoretically, and an increase in self-efficacy concerning some procedures for medical fields and various types of sciences, such as mathematics applications, as indicated by [8]. As confirmed [3] and with the development of technologies, 360-degree 3D video has become the best choice among students.

2.5 Studies related to mathematics

Research by [24] investigates the relationships between students' perceptions of learning in a VLab, the learning environment in mathematical and physical sciences laboratories, and self-efficacy for learning. The research sample consists of 262 female high school students in Taiwan. The survey is applied by making questionnaires to measure the desire to learn in scientific laboratories, the surrounding environment, and self-efficacy. The findings indicate that the student's perceptions of the scientific laboratory increase the contribution of their scientific and environmental perceptions, thus self-enhancing mathematics and physics, increasing adherence to science and cooperation among students, and reaching the level of deep understanding guided by laboratory activities.

Besides, a study conducted by [30] investigates the effect of using a virtual mathematics laboratory on the development of mathematical connection skills among fourth-grade female students in Makkah Al-Mukarramah, Saudi Arabia. The research sample consists of 25 students taught using the virtual mathematics laboratory. The research is applied to the algebra unit in the mathematics curriculum for fourth graders in Saudi Arabia, using the virtual mathematics laboratory prepared by the researcher. A mathematical association skills test is prepared after ensuring the validity and reliability of the research instrument. A one-group design with a pre and post-test is also used. The research recommends developing a mechanism for applying VLabs in teaching mathematical relations in mathematics curricula. It also recommends developing a vision for building virtual mathematics laboratories that integrates with real-life scenarios and other school subjects in primary education. The research encourages the support and allocation of financial resources to foster scientific research in the field of VLabs, aiming to conduct and disseminate further research studies.

Moreover, [15] explores the mathematical knowledge associated with the teaching of engineering among student teachers, as well as identifying the various types of connections made within this context. A quantitative and qualitative research approach is used to achieve the research objectives. The research sample includes 29 male and female students at the Department of Teaching Mathematics for the intermediate stage. The research instruments include the Diagnostic Teacher Assessments in Mathematics and Science (DTAMS) developed by the University of Louisville, the Mathematical Connections Evaluation Scale (MCE), and interviews with student teachers. The findings show that trained teachers focus more on procedural knowledge than conceptual knowledge during the teaching process.

2.6 Studies related to other sciences

Research work by [23] identifies the importance of effectiveness and self-efficacy, which play a role in behavioral changes to improve learning and overcome anxiety among students in laboratory experiments. The research is conducted on a sample of 1225 randomly selected undergraduate students from 25 higher education institutes in India. To achieve the research objectives, the research is applied in the first four stages. The first stage includes identifying the factors contributing to the low experimental self-efficacy of laboratory work through the traditional laboratory, while the second stage includes designing an interactive virtual laboratory that simulates reality and working through it. The third stage is to distribute an experimental group of students for self-efficacy inside the virtual laboratory to conduct the experiments without an assistant, while the fourth stage compares the experimental efficiency between students who conducted physical application experiments and others who conducted the experiments in the virtual laboratory. The results confirm the analysis of the general self-efficacy of students by accepting work on the computer, as they have scored higher than the average by measuring and obtaining the maximum from the test experience.

In the same context, [1] identifies the effectiveness of a teaching system based on AI to develop a deep understanding of nuclear reactions and the ability to self-learn among secondary school students. A sample of 65 female students in the first secondary stage is selected and divided into two groups: control and experimental. A test of deep understanding of interactions with a self-learning scale is designed as the research instrument. A system based on artificial intelligence is also prepared to teach the nuclear chemistry unit in the first secondary curriculum. The results of the study show the presence of statistically significant differences between the average scores of students in the post-application phase, with the experimental group outperforming the experimental group, demonstrating a high level of effectiveness of teaching based on AI in developing a deep understanding and self-learning abilities.

Moreover, [16] measures enthusiasm for using VLabs compared to 360-degree imaging studies in environmental chemistry. To achieve the research objectives, a semi-experimental approach is used. The research sample consists of 74 students in their fourth year of chemistry at the University of Singapore. The study is carried out by dividing the students into two groups: The first is taught through the web with 360-degree imaging, while the second is taught in virtual laboratories for direct simulation with the layers of the atmosphere in the photosphere. Then, they are subjected to a test of various questions about environmental chemistry. A survey is also published so that the response rate for the experiment is 80%, which indicates that enthusiasm is in favor of the virtual laboratory with the corresponding sites that offer 360 degrees. The findings show the students' general acceptance of the use of such technology to understand environmental chemistry.

[14] make a report on a VLab simulation and evaluation of an AP in Science program. The report studies how laboratory simulations can motivate students and improve their teaching tools. The evaluation was carried out on 78 faculty students. The results show the student's ability to link theory with practice and visualize operations. The findings also indicate that the use of VLab simulations contributes to increasing learning, activity, and motivation through an experiment on a randomly selected sample and subjecting them to pre- and post-tests. Besides, [7] investigates the effectiveness of 3D cameras and 360-degree videos in carrying out experiments in organic chemistry laboratories. The results indicate that it is a visually motivating and engaging show that captures many of the laboratory techniques of undergraduate organic chemistry. The findings, however, find that 360-degree videos add value in terms of their wide field of vision but pose some problems in terms of confusion and lack of focus. With the said research work and studies reviewed on the use and contribution of the VLab to increase learning, the research problem is given in the following part.

3 RESEARCH PROBLEM

The research problem is reflected in identifying students' negative attitudes towards mathematics and their unwillingness to study it at all levels of study. The research problem also lies in the significance of the reports received from the educational field showing the lack of activation of many mathematics applications based on AI as a result of several factors, including the lack of availability of computer laboratories updated with technological means, the weak experience among teachers to deal with virtual laboratories and the lack of a culture of VLabs in learning and teaching, especially in mathematics, as it is almost unavailable in many schools.

To confirm the significance of the research problem, the recommendations of previous studies, including [17], indicate the need to support education with advanced technological environments that improve self-learning among students and help them evaluate the cognitive, motivational, and emotional components of their learning. The related study by [1] also recommends the necessity of employing AI in designing chemistry curricula for the secondary stage of all kinds, which include expert systems, adaptive learning, and experimenting with learning systems based on AI in teaching subjects such as mathematics, physics, and chemistry. Accordingly, the research problem rests in examining the impact of VLabs based on AI on developing students' motivation towards learning mathematics so that it becomes the starting point in their learning.

4 RESEARCH QUESTIONS

Given the research problem, the research questions are:

1. Are there statistically significant differences between the members of the groups "experimental and control" on the motivation level of seventh-grade students towards learning mathematics due to the method of using the laboratory based on AI using visual imaging (3D) and teaching mathematics using the traditional approach?
2. What is the impact of using VLabs on the motivation of primary school students to learn mathematics?

5 RESEARCH OBJECTIVES

The following objectives are articulated to answer the research questions:

1. Find out whether there are statistically significant differences between the members of the groups "experimental and control" on the motivation level of seventh-grade students towards learning mathematics due to the method of using the laboratory based on AI using visual imaging (3D) and teaching mathematics using the traditional approach.
2. Identify the impact of using VLabs on the motivation of primary school students to learn mathematics.

6 RESEARCH HYPOTHESIS

Given the research problem, research questions, and research objectives, the research hypothesis is:

There are no statistically significant differences at ($0.05 \geq \alpha$) between the responses of the students of the research groups (experimental and control groups) on the scale of motivation towards learning mathematics among seventh-grade students.

7 SIGNIFICANCE OF THE RESEARCH

The research holds significance from both theoretical and practical aspects. The theoretical significance of the study lies in the fact that the findings may enrich the Jordanian and Arab libraries with previous studies addressing AI and VLabs in teaching mathematics and contribute to opening the opportunity for researchers and scholars to research the necessity of employing VLabs in mathematics instructions across various academic levels.

On the other hand, the practical significance of the research lies in guiding decision-makers to prepare training workshops for the available programs on mathematics for teachers and students and providing a procedural assessment of the difference between the theoretical study of mathematical applications and their representations in mathematics and the virtually practical application through the VLab. It is also hoped that this research may help decision-makers establish multiple VLabs for teaching mathematics and science courses.

8 RESEARCH LIMITATIONS

The findings of this research can be generalized in light of the following limitations:

1. **Human limitations**: This research is limited to a sample of students in the seventh grade in government schools.
2. **Spatial limitations**: This research is conducted at the School of Rettal International Academy in Amman - Jordan.
3. **Temporal limitations**: This research is conducted in the first semester of the academic year 2022/2023.
4. **Objective limitations**: This research is limited to the teach Geometric Shapes and Solids Unit from the mathematics course for the seventh grade.

The generalizability of the research findings is current research is determined by several factors, including the research population, the degree of seventh-grade students’ response, and the nature of the research instrument. The research findings can be applicable to populations that shares similarities with the research samples, provided that the instrument used demonstrates validity, reliability coefficient, and the students’ responses are objective of the target population.

9 METHOD

9.1 Research approach

The semi-experimental approach is used for its suitability for the research. The scale of motivation to learn mathematics is applied to the students of the first and second experimental groups and the control group after teaching the unit. In this research, the aim is to examine the influence of the independent variable, which is the utilization of VLabs based on AI and 3D visual imaging, on the dependent variable of students’ motivation to learn mathematics in the seventh grade. The study seeks to explore how the use of VLabs impacts students’ motivation levels when it comes to learning mathematics.

9.2 Research population

The research population consists of all (65358) male and female seventh-grade students in public and private schools in the Hashemite Kingdom of Jordan for the academic year 2022–2023.

9.3 Research sample

The research sample consists of 80 seventh-grade students distributed over three divisions at the School of Rettal International Academy of the Capital Governorate. The research sample is selected by the purposeful sampling approach because there is more than one division for the seventh grade, while the control group and the two experimental groups are randomly selected. Table 1 illustrates the distribution of the research sample among the control group and the two experimental groups.

Table 1. The distribution of the research sample to the control group and the two experimental groups

Group	Total	Division
Control Group: Teaching mathematics in the traditional approach.	27	A
First Experimental Group: Teaching mathematics using virtual lab-based AI.	26	B
Second Experimental Group: Teaching mathematics using a 3D-based virtual laboratory.	27	C
Total	90	–

9.4 Research Design

The semi-experimental approach is used through three groups: control, first experimental, and second experimental, and two measurements: pre and post, to assess the impact of VLabs based on AI on developing students' motivation towards learning chemistry, as follows:

EG1:	O1	X1	O1
EG2:	O1	X2	O1
CG:	O1		O1

Where:

EG1 = First experimental group (taught using AI-based virtual labs).
EG2 = Second experimental group (taught using 3D-based virtual laboratories).
CG = Control group (taught mathematics using the traditional approach).
O1 = Application of a scale of motivation to learn mathematics.
X1 = Experimental Processing1 (using AI-based virtual labs).
X2 = Experimental Processing2 (using 3D visual imaging-based virtual laboratories).

9.5 Research instrument

A Seventh Grade Mathematics Motivation Scale (SGMMS) is designed by exploring theoretical literature and previous studies related to the research problem and objectives, such as [5], [23]. A list of items related to mathematical motivation for seventh-grade students is drawn up, taking into account its linguistic formulation to be suitable for students at this stage. The scale is designed so that the students themselves answer its items through Google Forms. It is also formulated on a scale of 35 items in its initial form.

9.6 Seventh grade mathematics motivation scale validity

The scale is presented in its initial form to 12 specialized validators in scientific fields. The validators are asked to determine the degree of relevance of the items included in the scale and the degree of their comprehensiveness to measure the impact of VLabs on the motivation of seventh-grade students to learn mathematics, the degree of clarity of the items and their linguistic correctness, express any suggested modifications, suggest other items, and delete unnecessary items. After collecting the questionnaire, the proposed modifications are made, as they are agreed upon by 80% of the validators in their recommendations. In light of the modifications, the scale consists of 20 items after validation.

9.7 Seventh grade mathematics motivation scale validity

After applying the SGMMS to learn mathematics on the exploratory sample, reliability is calculated using the internal consistency method according to the Cronbach Alpha equation. The value of the overall reliability coefficient for the scale was 0.86, and this value is acceptable and suitable for the current study. The response is designed on the items of the motivation scale according to the five-point Likert scale as follows: very high (5) degrees, high (4) degrees, moderate and (3) degrees, low (two degrees), very low and (one degree) only. In this way, students' grades are calculated based on the items on the motivation scale.

Therefore, the scale has achieved appropriate validity and reliability indications that allow it to be applied to the original sample of the study, as the scale, in its final form, consists of 20 items.

10 RESEARCH VARIABLES

10.1 Independent variable

It includes the teaching approach variable and has three levels:

- Teaching mathematics in the traditional approach.
- Teaching using VLabs based on AI.
- Teaching using VLabs based on 3D visual imaging.

10.2 Independent variable

Students' motivation to learn mathematics.

11 STATISTICAL PROCESSING

The following statistical processing is used to answer the research questions and hypothesis:

- **Means and standard deviations**: They are used to find out the responses of the research sample on the items of the motivation scale, as shown in Table 2.
- **One-Way ANOVA "analysis of variance"**: It is used to reveal the significance of differences in the responses of the students of the control group, the first experimental group, and the second experimental group on the motivation scale for learning mathematics, as shown in Table 3.
- **Scheffé's method**: It is used to identify the source of differences in the research groups' responses (AI, 3D, and traditional approach) on a scale of motivation to learn mathematics, as shown in Table 4.

Table 2. The means and standard deviations of the research sample's responses on the seventh-grade students' motivation scale to learn mathematics arranged in descending order according to its items

No.	Text of Item	Experimental Group No. 1		Experimental Group No. 2		Control Group	
		M	SD	M	SD	M	SD
1	I feel an increase in my interest in learning mathematics.	3.78	0.94	4.08	0.99	3.34	1.03
2	I desire to do more research and increase my knowledge of mathematics.	4.28	0.92	3.90	0.86	3.33	0.93
3	I have fun while learning mathematics.	4.16	0.92	3.76	0.83	3.14	0.90
4	I am interested in exchanging experiences and information about mathematics with my colleagues.	3.59	1.16	3.34	1.08	2.46	0.83
5	I like to learn the scientific subject of mathematics more deeply and better.	4.06	1.05	3.45	0.87	2.10	0.82
6	I am curious about the applications and representations of mathematical concepts.	3.76	0.96	3.45	0.95	3.10	0.86
7	I want to relate what I learn in mathematics to real life.	4.10	0.97	3.20	1.21	2.20	1.52
8	I feel more confident while doing the application and representation of mathematical concepts.	4.20	0.85	4.00	0.95	3.25	1.05
9	I work on enriching my knowledge and skills when making applications and representations of mathematical concepts.	3.00	1.10	3.40	0.90	3.00	1.20
10	I wonder and inquire about the applications and representations of mathematical concepts.	4.00	0.98	3.33	1.80	2.10	0.99
11	I feel satisfied when I develop my knowledge and skills in mathematics.	3.25	1.10	3.10	0.89	3.00	0.88
12	I quickly do the extra homework for the subject.	3.40	1.25	2.60	0.86	2.50	0.87
13	I make sure to prepare for mathematics regularly.	3.65	1.12	2.20	1.90	2.23	0.90
14	I feel that time quickly passes during math class.	4.06	1.05	3.20	0.98	2.10	0.98
15	I think my concentration and attention increase while learning mathematics.	3.60	1.00	3.10	1.25	2.60	1.20
16	I make sure to complete applications and representations of mathematical concepts.	4.23	0.79	3.16	0.96	3.07	1.10
17	I like to participate in contests and competitions related to mathematics.	3.25	0.86	3.10	1.12	2.30	1.06
18	I work with my classmates with pleasure during math lessons.	3.50	1.05	3.25	0.93	2.20	1.45
19	I invest my time in learning and acquiring skills related to mathematics.	3.30	0.70	2.00	1.45	2.50	0.94
20	I stay away from boredom while studying mathematics.	3.90	0.40	2.15	0.95	2.15	1.20
The impact of using VLabs on the motivation of elementary school students in learning mathematics.		3.75	0.96	3.19	1.09	2.63	1.04

Table 2 shows the responses of the research sample groups to the impact of using VLabs on their motivation to learn mathematics have varied, as the mean of the responses of the first experimental group taught using VLabs based on AI is 3.75 with a standard deviation of 0.96. however, the mean of the responses of the second experimental group taught using VLabs based on 3D visual imaging is 3.19

with a standard deviation of 1.09, while the mean of the responses of the control group taught in the traditional approach is 2.63 with a standard deviation of 1.04. One-Way ANOVA "analysis of variance" is used to find out the level of statistical significance of the differences in the means of the responses of the three research groups, the "research sample," on the SGMMS to learn mathematics. Table 3 illustrates the results.

Table 3. Results of One-Way ANOVA "analysis of variance" for determining the statistical significance of differences in the research groups' responses on the motivation scale for learning mathematics

<table>
<tr><th>Source of Variation</th><th>Sums of Squares</th><th>Degrees of Freedom</th><th>Mean Square</th><th>F-Value</th><th>Statistical Significance</th></tr>
<tr><td>Between Groups</td><td>12.544</td><td>2</td><td>6.272</td><td rowspan="3">26.990</td><td rowspan="3">0.05*</td></tr>
<tr><td>Within Groups</td><td>13.246</td><td>57</td><td>0.232</td></tr>
<tr><td>Total</td><td>25.790</td><td>59</td><td></td></tr>
</table>

Note: *Statistically significant.

Table 3 indicates statistically significant differences in the responses of the research groups, as the calculated "F" value is 26.990, with a significance level 0.05*, demonstrating the statistical significance of these values. Post-comparisons are made using "Scheffé's" method to reveal the source of differences in the research groups' responses on the motivation scale for learning mathematics, as shown in Table 4.

Table 4. Results of post-comparisons using scheffé's method to determine the source of differences in the research groups' responses (AI, 3D, & traditional approach) on the mathematics learning motivation scale

<table>
<tr><th colspan="2" rowspan="2">Group X</th><th>Artificial Intelligence (AI)</th><th>Visual Imaging (3D)</th><th>Traditional Approach (TA)</th></tr>
<tr><th>3.75</th><th>3.19</th><th>2.63</th></tr>
<tr><th>Artificial Intelligence (AI)</th><th>3.75</th><td>–</td><td>–0.56*</td><td>–1.12*</td></tr>
<tr><th>Visual Imaging (3D)</th><th>3.19</th><td>0.56*</td><td>–</td><td>–0.56*</td></tr>
<tr><th>Traditional Approach (TA)</th><th>2.63</th><td>1.12*</td><td>0.56*</td><td>–</td></tr>
</table>

Note: *Statistically significant.

As shown in Table 4, the source of the statistically significant differences between the responses of the research groups on the measure of motivation to learn mathematics is between the responses of the students in the first experimental group on the one hand and each of the second experimental group and the control group on the other hand. The differences between the means of the first experimental group and the second experimental group are 0.56, while the differences between the means of the first experimental group and the control group are 1.12.

The results also show statistically significant differences between the responses of the research groups on the motivation scale for learning mathematics, i.e., between the responses of students in the second experimental group and the control groups, as the differences between the means of the two groups are 0.56. Given these results, it can be said that the students of the first experimental group have more motivation than the students of the second experimental group and the students of the control group, on the one hand. In addition, the students of the second experimental group have more motivation than the students of the control group, on the other hand.

12 RESULTS AND DISCUSSION

The hypothesis associated with the study questions stipulates that "there are no statistically significant differences at (0.05 ≥ α) between the responses of the students of the research groups (experimental and control groups) on the scale of motivation towards learning mathematics among seventh-grade students". The results indicate statistically significant differences in the responses of the research groups "artificial intelligence (AI), 3D visual imaging, and the traditional approach" on the motivation scale for learning mathematics.

The results also demonstrate that the source of the statistically significant differences between the responses of the research groups on the scale of motivation to learn mathematics is the responses of students in the first experimental group (artificial intelligence, AI) on the one hand and in the second experimental group (3D visual imaging) and the control group (traditional approach) on the other hand, in favor of the group The first experimental. The results also show statistically significant differences between the responses of students in the second experimental group (3D visual imaging) and the control group (real-world laboratory) on the motivation scale to learn mathematics in favor of the second experimental group.

This result is consistent with the result of the study [14], indicating that the use of virtual laboratory simulation contributes to increasing learning, activity, and motivation because it adds fun to learning and attracts a variety of methods, along with the ability of the students to simulate freely per their trends and desires for science. It also agrees with the result of the study [1], indicating statistically significant differences between the mean scores of female students in the post-application in favor of the experimental group, which hints at a high level of effectiveness of teaching based on artificial intelligence in developing deep understanding and self-learning in mathematics.

This finding is also in line with the result of the study [23], indicating the improvement of learning and overcoming anxiety among students in performing laboratory experiments and confirming the analysis of the general self-efficacy of students by accepting work on the computer compared to the VLab. This result is also consistent with the result of the study [24], indicating that students' perceptions of the scientific laboratory increase the contribution of their scientific and environmental perceptions, resulting in self-promotion of science, and an increase in adherence to science, and cooperation among students to reach the level of deep understanding that is guided by mathematical applications. This result can be attributed to the fact that the use of VLabs in all their forms makes the students lively and active, motivating them to learn and explore scientific fields in mathematics that do not allow them to do so within the regular computer laboratories.

13 RECOMMENDATIONS

Based on the results of the study, the research recommends encouraging male and female teachers of mathematics and other scientific subjects to use the technologies from the VLabs within the training and qualification programs provided to them. Another recommendation is urge all specialists in mathematics and other scientific subjects to take advantage of the free websites of VLabs for teaching mathematics and other scientific subjects. The research also recommends urging researchers in teaching mathematics and other scientific subjects to employ AI techniques to serve the educational-learning process, facilitate the learning process for students, and references.

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