
| RESEARCH ARTICLE

The Impact of Augmented Reality-Based Applications on Students' Motivation towards Learning Math and in their Academic Achievement

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| ABSTRACT

The current study aims to verify whether students' motivation towards learning math and their academic achievement is affected by using (AR) applications in learning math. The study followed the quasi-experimental approach to achieve the objectives. The sample is (46) students in seventh grade distributed as two groups: control and experimental, (23) students in each. AR-based applications were used to explain the educational content to the first group, while the second group was taught using conventional methods. Two instruments were developed to collect data for the study: a scale of motivation towards learning math and an achievement test in math. The results indicated that the experimental group students' motivation towards learning math was significantly enhanced after treatment, and their academic achievement was apparently improved. Accordingly, the study recommends using (AR) applications in teaching math topics to create a more interactive learning environment that may enhance learners' motivation and improve their academic achievement.

| KEYWORDS

Augmented Reality, Motivation towards Learning, Academic Achievement, Math.

| ARTICLE INFORMATION

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1. Introduction

Recently, cognitive theories and educational trends have encouraged benefiting from the capabilities provided by technology in order to effectively achieve learning goals and enhance its outcomes. The technological innovations may be used to create an interactive learning environment that's compatible with learners' different characteristics and needs.

Augmented reality (AR) is one of the technological innovations that have been used in education for more than (25) years. It provides learners with interactive experiences by enhancing the real world's objects with perceptual information generated by the computer (Garzón, 2021). This technology has had a significant impact on different fields of education (Elmqaddem, 2019).

AR-applications are mobile-based learning that aims to enhance students' experience, improve their understanding, and increase their motivation to learn (Tzima et al., 2019). (AR) applications are flexible and attractive. They are used to enrich the educational content by adding interesting elements, such as 2D and 3D images, video clips, animations, etc., which allow learners to experiment and explore learning according to their individual differences (J López-Belmonte et al., 2023). However, (AR) technology is constantly evolving; thus, more research about how to utilize this technology in the best way in education must be applied (Kljun et al., 2020).

Motivation is one of the important characteristics of learners; it is what determines their behavior and pushes them towards achieving their educational goals (Filgona et al., 2020). Motivation is the key to learning; it enhances the learner's ability to receive and process information and thus build knowledge (Meece, 2023).

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Students' motivation towards learning affects their academic achievement, as students who have high motivation pay more attention to the educational process and make more efforts to improve their performance and effectively achieve learning goals (Tokan and Imakulata, 2019).

Mathematics is a science that relies on high logical and thinking skills to solve problems. Several abstract concepts are included in math, which students have obvious difficulties with understanding, and teachers have difficulties with explaining and simplifying, which may reduce students' academic achievement and impede their motivation towards learning (Kilpatrick, 2020). Some previous studies indicated that using technological innovations such as (AR) in teaching math may help with overcoming these difficulties (Hansson, 2020), (Ibáñez et al., 2020) and (Gecu-Parmaksiz and Delialioglu, 2019).

Accordingly, the aim of the current study is to address the following questions:

1. Is students' motivation towards learning math affected by using (AR) applications?
2. Is students' academic achievement in math affected by using (AR) applications?

2. Literature Review

Assessing the potential of (AR) technology in education has gained clear attention in several recent studies; for instance, Erbas and Demirer (2019) investigated (AR) technology's effectiveness in students' motivation and achievement in biology. The study was applied at a high school in Turkey. The sample consisted of (40) students in ninth grade divided into two groups: control and experimental. The researchers found that the motivation of the experimental group was more enhanced than that of the control group after treatment. In contrast, using (AR) didn't significantly improve the academic achievement of the students in the experimental group.

Moreover, Gecu-Parmaksiz and Delialioglu (2019) assessed the potential of (AR) technology to increase students' understanding of some shapes in geometry. The study followed the quasi-experimental methodology. The sample was (72) students distributed over control and experimental groups. The results of the study illustrated that students who learned geometric shapes using (AR) manipulatives achieved higher scores, and their understanding of the material significantly increased.

Additionally, Chen (2020) examined the capabilities of (AR) in students' achievement and motivation while learning English as a foreign language. The study was applied to sixth grade students at a Taiwanese school. The sample consisted of two groups: control and experimental (49) students in the first and (48) students in the second. The results of the study showed that students who learned using (AR) became more motivated towards learning English, and their academic achievement significantly improved.

Furthermore, Kaur et al. (2020) presented a visualization approach using (AR) technology to teach some topics in engineering. The study was applied to the School of Engineering at Deakin University in Australia. Thirty-four undergraduate students participated in the experiment, and the impact of (AR)-based learning approach on students' motivation was assessed. The results of the study indicated that (AR) technology has significantly enhanced students' motivation toward learning.

In addition, Ibáñez et al. (2020) designed an (AR)-based application and verified its effect on students' achievement in geometry and motivation. The study was applied to (93) Students at a middle school in Mexico. The study found that students who learned with (AR) achieved higher scores in the post-test than those who learned with conventional methods.

Additionally, Alqarni (2021) applied an experiment in Jordan to examine the impact of (AR) technology in enhancing special needs students' attitudes towards learning science and in improving their achievement. The study followed the quasi-experimental approach. The sample consisted of (24) students in sixth grade divided equally into two groups: control and experimental. The study showed that (AR) technology has positively affected students' achievement and promoted positive attitudes toward learning science.

Further, Baabdullah et al. (2022) assessed students' experience of using (AR) applications in learning. This study is quantitative; 500 undergraduate students at four Saudi Arabian universities participated in a questionnaire. The results of the study found that (AR) has improved students' performance, reduced their cognitive load, and made them better able to achieve learning outcomes.

More recently, Ciloglu and Ustun (2023) examined the impact of (AR) technology on students' self-efficacy, motivation and attitudes toward learning biology. The study was applied at a high school in Turkey. The researchers followed the quasi-experimental methodology with a sample of (71) students divided unequally into two groups: control and experimental. The study found that the self-efficacy of the experimental group became statistically higher than the self-efficacy of the control group. However, no significant effect of (AR) technology on the students' motivation and attitudes towards learning biology was found.

All previous studies attempted to evaluate the leverage of (AR) technology in school and university education by considering important aspects, i.e. motivation towards learning and academic achievement. The application of the current study is based on the recommendations of most of the previous ones that encouraged examining (AR) technology's effects on education. The current study is similar to most previous ones in that it follows the quasi-experimental method to validate the effectiveness of (AR) technology.

On the other hand, this study is distinguished from previous ones as it uses virtual manipulatives provided by (AR)-based mobile applications available in App Stores to achieve its objectives. Also, the current study focuses on investigating the impact of using (AR) applications for clarifying the laws of calculating areas and volumes of 3-D shapes for the seventh graders, as this matter has not been studied before (to the researcher's knowledge). In addition, the current study is one of the few local studies about the effectiveness of (AR) in education in Jordan.

3. Methodology

The current study follows the experimental approach with the quasi-experimental design as it is the most appropriate to verify the impact of using (AR) applications on students' motivation towards learning math and their academic achievement. The study was applied to control and experimental groups. The data collection instruments were applied to both groups before and after treatment. The treatment expresses teaching the educational content to the experimental group using (AR) applications for four weeks, while the control group is taught the same content using conventional methods (the textbook and the board).

3.1 Study Sample

The study sample includes (46) male and female students in seventh grade at a private school in Amman-Jordan. The sample is distributed over two groups: control and experimental; (23) students in each.

3.2 Data Collection Instruments

3.2.1 A Scale of Students' Motivation towards Learning Math

In order to measure the students' motivation towards learning math, a scale was developed based on Keller's model (ARCS), which is a teaching design model concerned with motivating students towards learning by applying a set of methods that suit their abilities, characteristics, and needs (Li and Keller, 2018). Based on Keller's model, the following dimensions were determined for the scale of motivation towards learning math:

Attention: Refers to the degree of students' attention to the educational material and their keenness to implement its activities and interact with it.

Relevance: Refers to the degree to which the objectives, content, activities, and requirements of the educational material fit the students' needs, personal interests, and previous experiences.

Confidence: Refers to the degree to which students believe that the educational material develops their skills and experience, supports their knowledge, and leads to their success.

Satisfaction: Refers to the degree to which students feel that the educational material supports them and provides them with real and clear benefits, which make them desire to learn more about it.

The scale of motivation towards learning math consists of (20) multiple-choice items, five for each of the previous dimensions. For each item, there are five points according to the Likert scale. The scores on the scale range from (20) to (100).

3.2.2 Achievement test in math

This test aims to measure the degree to which seventh graders achieved the educational objectives of the seventh unit of the math book, which is about finding areas and volumes for 3-D shapes. The test consists of (20) multiple-choice questions. The test scores range from (0) to (20).

3.2.3 Validity of data collection instruments

To confirm the validity of the scale of motivation towards learning math and the achievement test in math, these instruments were presented to seven arbitrators consisting of professors at the Faculty of Educational Sciences at the University of Jordan (specializing in educational technology) and teachers with experience in teaching math. After taking into account their comments, a few items were reformulated and approved in their final form.

3.2.4 Reliability of data collection instruments

The internal consistency of the items of the motivation scale towards learning math was determined by calculating Cronbach’s alpha factor, the value of (0.746), which is a significant value at the level ($\alpha \leq 0.01$), which means that the scale is reliable.

As for the achievement test in math, the internal consistency was calculated by applying the Kuder Richardson equation (KR-20). The value was (0.846), which is a significant value at the level ($\alpha \leq 0.01$), which means that the test is reliable.

4. Results and Discussion

4.1 The impact of (AR) on motivation towards learning math

To answer the first question of the current study, which is “Is students’ motivation towards learning math affected by using (AR) applications?” the motivation scale was applied to the students in both groups: control and experimental before and after treatment. Table (1) shows the means and standard deviations (σ) for students’ scores.

Table (1): Means and standard deviations on the motivation scale towards learning math

Group	N	Results before Treatment		Results after Treatment	
		Mean	σ	Mean	σ
Control	23	61.52	14.21	62.65	14.41
Experimental	23	62.09	14.39	84.17	7.08
Total	46	61.80	14.15	73.41	15.63

Table (1) shows apparent improvement in the mean scores of the experimental group on the motivation scale towards learning math after the treatment, as it was (62.09) and became (84.17). There is no apparent improvement in the mean scores of the students in the control group after the treatment, as it was (61.52) and became (62.65). To determine whether these differences are statistically significant at ($\alpha \leq 0.05$), an Analysis of Covariance (ANCOVA) was used. Table (2) shows the results.

Table (2): ANCOVA results for students’ scores on the scale of motivation towards learning math after the treatment

No.	Source of variation	Sum of Squares (SS)	DF	Mean of Squares (MS)	F	Sig.	Partial η^2
1	Pre	4191.97	1	4191.97	121.91	* <0.001	0.74
2	Group	5135.32	1	5135.32	149.35	* <0.001	0.78
3	Error	1478.55	43	34.39			
4	Adjusted Total	10997.15	45				

ANCOVA demonstrated that ($F=149.35$, $\text{sig}<0.001$, $\text{partial } \eta^2=0.78$) for the experimental group after the treatment, which is significant at ($\alpha \leq 0.05$), meaning that using (AR) applications enhanced students’ motivation towards learning math by (78%), which is a significant effect.

In addition, table (3) shows the adjusted means scores and standard error for the control and experimental groups on the scale of motivation toward learning math after the treatment. It’s apparent that the mean that was adjusted by (ANCOVA) is in favor of the experimental group (83.98).

Table (3): Adjusted means scores and standard error on the scale of motivation towards learning math

No.	Group	N	Adjusted Mean	Std. Error
1	Control	23	62.85	1.22
2	Experimental	23	83.98	1.22

The positive impact of (AR) applications in enhancing students’ motivation towards learning math may be referred to the capability of these applications to present educational activities through attractive and interesting, i.e. 3D models, where the learners are able to view and analyze these models from different aspects, which gives them a deeper understanding of the complex information in math. In addition, (AR) applications promote collaborative learning and social interaction among learners through

working together and actively participating in solving problems. Moreover, (AR) applications provide rich interactive educational content that increases student’s attention and willingness to learn more.

4.2 The impact of (AR) applications on academic achievement in math

To answer the second question of the current study, which is “Is students’ academic achievement in math affected by using (AR) applications?” an achievement test was applied to the students in both groups: control and experimental before and after treatment. Table (4) shows the means and standard deviations (σ) for students’ scores.

Table (4): Means and standard deviations on the achievement test in math

Group	N	Results before Treatment		Results after Treatment	
		Mean	σ	Mean	σ
Control	23	9.17	3.41	11.83	3.94
Experimental	23	8.91	3.79	16.23	2.76
Total	46	9.04	3.56	14.02	4.03

Table (4) shows apparent improvement in the mean scores of the experimental group on the achievement test in math after treatment, as it was (8.91) and became (16.23). While there is no apparent improvement in the mean scores of the control group after treatment, as it was (9.17) and became (11.83). To determine whether these differences are significant at ($\alpha < 0.05$), an Analysis of Covariance (ANCOVA) was used. The results are in Table (5).

Table (5): ANCOVA results for the achievement test in math after the treatment

No.	Source of variation	Sum of Squares (SS)	DF	Mean of Squares (MS)	F	Sig.	Partial η^2
1	Pre	81.79	1	81.79	8.23	0.006	0.16
2	Group	231.53	1	231.53	23.29	* < 0.001	0.35
3	Error	427.43	43	9.94			
4	Adjusted Total	730.98	45				

ANCOVA demonstrated that ($F=23.29$, $\text{sig} < 0.001$, partial $\eta^2=0.35$) for the experimental group after treatment, which is significant at ($\alpha < 0.05$). This means that using (AR) applications enhanced students’ achievement in math by (35%) which is a significant effect.

In addition, table (6) shows the adjusted means scores and standard error for the control and experimental groups on the achievement test in math after the treatment. It’s apparent that the mean adjusted by (ANCOVA) is higher for the experimental group (16.27).

Table (6): Adjusted means scores and standard error on the achievement test in math

No.	Group	N	Adjusted Mean	Std. Error
1	Control	23	11.78	0.66
2	Experimental	23	16.27	0.66

The positive impact of (AR) applications in improving students’ achievement in math may be due to the fact that these applications provide information using multi-sensory ways, which helps to better absorb information for all learning styles. Additionally, (AR) applications present complex mathematical information in simpler, easier, more attractive and more interactive forms, which improves students’ abilities to receive, process, understand and store this information and reflects positively on their scores and academic achievement. Moreover, tools available by (AR) applications can attract students’ attention and concentration during learning and push them to use higher thinking skills, which helps them to memorize the information and compete to achieve higher scores.

4.3 Comparing the current study’s results with the previous studies’

The results of the current study are consistent with the results of (Ibáñez et al., 2020), (Gecu-Parmaksiz and Delialioğlu, 2019), (Chen, 2020), (Kaur et al., 2020), (Alqarni, 2021) and (Baabdullah et al., 2022); where all of these studies found a positive effect of

(AR) technology in enhancing students' motivation towards learning and in improving their academic achievement in different subjects.

However, Erbas and Demirel (2019) found a significant effect of (AR) technology in enhancing students' motivation towards learning, but the researchers did not find a significant improvement in the academic achievement that refers to using (AR) in education.

Additionally, Ciloglu and Ustun (2023) found that the self-efficacy of the students became statistically higher with using (AR) in learning. On the other hand, the study did not find a significant effect of (AR) technology in enhancing the motivation of the students and in improving their attitudes toward learning.

5. Study Limitations

The results of the current study can be generalized after considering the following factors:

- The study was applied to a sample of (46) students in seventh grade.
- The study was applied in a private school in Amman-Jordan.
- The study was applied for four weeks during the second semester of the academic year 2022-2023.
- The students' results were statistically analyzed using ANCOVA to determine the effect of the independent variable, i.e., augmented reality-based applications, on the dependent variables, i.e., motivation towards learning math and academic achievement.

Additionally, the results of the current study are limited to the nature of its methodology, the characteristics of the study individuals, the study tools and the extent of their validity and reliability.

6. Conclusion

In this study, (AR)- based applications were used to teach a unit of math to seventh-grade students, and its effect on students' motivation towards learning and their academic achievement was verified. The study followed the quasi-experimental method; the study sample was divided into two groups: experimental and control. The first group was taught using (AR) applications, while the second group was taught using conventional methods. The results showed that the students who were taught with (AR) technology became highly motivated to learn math, and their academic achievement was significantly improved.

Based on the results of the current study, the researchers highly recommend teachers use (AR) applications to teach mathematical concepts. In addition, it is recommended to consider (AR) applications with all school subjects in order to present interactive learner-centered educational content. Further, the researchers suggest putting more effort towards developing teaching and learning methods that enhance students' understanding of math topics and increase their academic achievement, which makes them more motivated to learn math.

However, future research on the long-term impact of augmented reality-based applications in learning motivation and academic achievement is necessary since monitoring learners over a prolonged period of time can shed light on the impacts' sustainability and potential long-term persistence.

Moreover, researchers suggest applying future studies that compare augmented reality's efficacy to that of other instructional technologies or conventional methods of instruction. For instance, they may compare augmented reality (AR), virtual reality (VR), mixed reality (MR), or traditional classroom training.

Finally, we suggest analyzing how professional development and teacher training can successfully incorporate augmented reality into the classroom. Researchers may apply studies that examine the ways in which pedagogical practices, attitudes, and beliefs of teachers affect the application of AR-enhanced instruction.

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