The Impact of Augmented Reality on Developing Students' Mathematical Thinking Skills

Ali Suwayid Alqarni† and Ruzaiqa Rezqallah Alzahrani††

Umm Al-Qura University, Makkah, Makkah, SA

Summary
The current endeavor aimed to study the effect of augmented reality (AR) on developing mathematical thinking skills in the Maths Course. This study, experimented on students of second-year middle school in Jeddah, recruited 65 students using the stratified random sampling technique. This body of learners was divided into two groups: an experimental and a control group. The experimental group (n= 32) used AR in their study, and the control group (n=33) underwent the traditional learning mode. The study intended to unveil any statistical differences between the scores of the control and experimental groups in the post-test of the mathematical thinking skills test. Towards this end, the researcher used the quasi-experimental approach based on two groups to compare them and verify the effect of the independent variable (augmented reality) on the dependent variable (mathematical thinking). The researcher constructed the mathematical thinking skills test and augmented reality program. Findings evinced an existence of statistically significant differences between the mean scores of the experimental and control groups in the post-test in mathematical thinking skills as a whole. This significance (α=0.05) was in favor of the students of the experimental group. Statistically significant differences were also found between the mean scores of the experimental group in the pretest and posttest of the test mathematical thinking skills in favor of the posttest (α=0.05). The effectiveness of the program continued three months after the first test. Based on the findings, the study provided viable recommendations, at the top of which is harnessing the software used in the study employing augmented reality in the Maths textbook of the second intermediate grade (Chapter 6). The study also recommends reconsidering the design of teaching mathematics courses and enhancing teaching Maths in light of the augmented reality as a successful teaching method. Add to that motivating the Maths teachers to learn and utilize technologies, especially AR, and foreseeing the future and researching emerging and newly introduced technologies.

Keywords: *Augmented reality, mathematical thinking skills, middle school students*

Introduction

The current era has undergone unprecedented changes in all facets of life, especially education, which is construed as the face of societies. It constitutes countries' welfare, prosperity and progress. Because we live in an era of scientific and educational competition, education has largely developed, including the scientific revolution of information and communication technology. The rapid and successive development of technology instigates educators to constantly search for educational methods that align with such development and help learners self-learn, as advocated by the constructivist theory. Technology has contributed to the development of the pillars of the educational process: the teacher, learner, curricula, means, methods, among others, by providing an interactive learning environment.

Keen interest in e-learning and the multiplicity of technology-based strategies have led to augmented reality (AR) adoption. It is one of the modern teaching methods in education. Modern technologies are integrated into the learner's environment. Arguably, AR provides appropriate solutions to abstract concepts requiring complex operations and experiments or those related to the void. According to [1], AR integrates the virtual world with the real world via various technologies to show digital content such as images, videos, three-dimensional shapes, websites, and the like. It betters the learner's interaction with digital content and makes it rememberable.

Many studies, e.g., [2, 3, 4] deviled into augmented reality have shown that it positively impacts the development of all kinds of thinking and academic achievement. Such technology has also been proved to be an effective teaching technique in many fields of study such as science, computers and others as study [5, 6].

Mathematics is an abstract science that humans creatively brought into existence, taking its power from the discipline itself. Arguably, mathematics serves all sciences and is one of their most important pillars. Developing the learner's mental abilities directing them towards flexibility and originality can only be done by studying and teaching mathematics. Modern mathematics curricula are based on learning outcomes related to the student's mental and thinking abilities, such as research, analysis, critical and creative thinking, and possession of induction, induction and problem-solving skills. For these goals to be real on the ground, it is necessary to make teaching mathematics vigorous and bring more consistency and harmony between what is presented in mathematics and what links it with other fields of science. This link relates to various thinking skills such as induction, induction, generalization, expression by symbols, analysis, modeling, mathematical proof, reasoning, criticism and evaluation. Add higher-order thinking skills, such as creative and critical thinking, decision-making, problem-solving and metacognitive thinking. As stated in the international school mathematics standards, and by the very nature of mathematics, along with the logical connection of its educational contents, [7] viewed it as a pioneer in many fields of science and

Manuscript received March 5, 2022
Manuscript revised March 20, 2022
https://doi.org/10.22937/IJCSNS.2022.22.3.71

knowledge. It develops different ways of thinking in general and creative and critical thinking styles in particular.
Mathematical thinking is considered one of the most critical modern trends that transcend mathematics. Some consider it the backbone of individuals' scientific thinking as it promotes mathematical discussions and proofs to such a large extent.
Several studies, including [4], have pointed out the significant impact of using augmented reality in mathematics. It encompasses several educational media that help identify parts, dimensions, and characteristics. It also visualizes and verifies information in such a way that helps female students to deal with facts, abstract scientific concepts and generalizations more effectively.
It goes without saying that some have difficulties understanding and comprehending abstract concepts and skills included in mathematics. Many teachers find it difficult to communicate these abstract concepts, which likely leads to a decline in the level of mathematical thinking skills. As a result, students' academic achievement in mathematics is low.

There are some justifications for augmented reality in education. [8] mentioned one of these justifcations. The author pointed out that it increases understanding of scientific content in certain topics. Similalry, it has a more effective impact on teaching students than the impact of other means, such as books, videos, or desktop computers. Additionally, the content acquired through augmented reality is established in the memory more firmly than what the student acquires through traditional means without augmented reality. The use of augmented reality also boosts students' enthusiasm when augmented reality is used in education. [9] contends that AR helps students learn school subjects that they can not touch or perceive only through a real first-hand experience such as astronomy and geography.

Quesiton of the study:
Touched on above, the overriding question the present study address is this:

- What is the effect of using augmented reality in developing the mathematical thinking skills of the second intermediate grade female students in Jeddah?

The following assumption was formulated to address this research question.
- There are no statistically significant differences between the mean scores of the experimental group students and the average scores of the control group students after applying the program to the test of mathematical thinking skills.

Methods and participants
The study was conducted using the quantitative method, with a quasi-experimental design to test and answer the study's hypotheses. The study sample consists of 65 female students divided into two groups, one representing the experimental group and the other representing the control group.
The study was conducted using the quantitative method, with a quasi-experimental design to test the hypothesis. The sample consisted of 65 female students divided into two groups, one representing the experimental group and the other representing the control group.

Instruments

A test of mathematical thinking skills was prepared to achieve the goal of the study. The validity of the test was measured a group of specialized arbitrators from faculty members in Saudi universities and specialists in mathematics curricula and teaching methods. These expersts gave feedback in terms of clarity of the questions and their fitting to the dimension that was
developed to measure as well as suitability to the nature of the sample it is used with, besides any necessary modification to its formulation. The reliability of the test and its five dimensions was also verified, using the split-half method using the Spearman-Brown formula, Analysis of Variance using the Couder-Richardson 20. The reliability coefficients are displayed in following table.

Table 1
Relibaility Coefficients of the Mathematical Thinking Skills Test

No.	**Dimensions**	**Spearman – Brown Coefficient**	**Couder-Richardson 20 Coefficient**
1	Deduction	0,87	0,79
2	Induction	0,86	0,80
3	Expression with emoticons	0,87	0,81
4	Modeling	0,89	0,83
5	Mathematical proof	0,88	0,82
	Scale as a whole	0,91	0,84

Table 1 indicates that the values of reliability coefficients ranged between 0.79 and 0.91. All the values, which are high, are indicative at the level of significance of 0.01. This is a good indication of the reliability of the test. hence, it is reliable to use the test in the current study.

Results
The t-test was used to statistically verify the hypothesis raised in the introduction of this study. It was used to identify the significance of the differences between the mean scores of the members of the experimental group and the mean scores of the control group members in

performance on the test of mathematical thinking skills [dimensions - total score] after implementing the program. As shown in Table (2), the effect size was also calculated.

Table 2
T-Test results Comparing the Control and Experimental Groups' Scores in Mathematical Thinking Skills Test

Varaiables Dimentions	Group	N	M	St	t	α	η^2	Effect size
Deduction	Control	33	3,697	1,741	3,464-	0,01	0,160	large
	Experimental	32	4,969	1,150				
Induction	Control	33	0,970	0,728	6,402-	0,01	0,394	large
		32	1,875	0,336				
Expression with emoticons	Experimenta	33	1,758	1,173	4,653-	0,01	0,256	large
		32	2,781	0,420				
Modeling	Control	33	1,939	1,029	3,925-	0,01	0,197	large
		32	2,719	0,457				
Mathematical proof	Experimenta	33	3,848	1,805	3,861-	0,01	0,191	large
		32	5,188	0,780				
Scale as a whole	Control	33	12,212	5,249	5,179-	0,01	0,299	large
		32	17,375	2,091				

N=65, t=1.96 α (0.05), t=2.58 α (0.01)

Both Abu Hatab and Sadiq [10] speculate that the effect that explains about 1% (0.01) of the total variance indicates a weak effect. The authors also affirm that the effect that explains about 6% (0,06) of the total variance indicates a medium effect. The effect that explains about 14% (0,14) or more of the total variance indicates a significant effect. Data in Table (2) clearly shows that the t-values are significant at the significance level 0.01. This indicates that there are statistically significant differences between the mean scores of the students of the experimental group (that were exposed to the program) and the control group (that was not exposed to the program) in performance on the test of mathematical thinking skills (dimensions - total score) in favor of the experimental group students. As it is clear from the table, the values of the effect size for testing mathematical thinking skills (dimensions - total score) are large, which indicates the effectiveness of using augmented reality in developing mathematical thinking skills of the experimental group students, and thus the first hypothesis is achieved.

Discussion

The result of this hypothesis indicates statistically significant differences between the mean scores of the experimental and the control groups regarding learners' performance on the test of mathematical thinking skills (dimensions - total score) after implementing the program, in favor of the experimental group students. The result of this hypothesis is in line with the results of [11, 7, 12, 13, 14, 15, 16], which confirms an improvement in mathematical thinking skills.

As indicated in the table above, there are statistical indications of the impact of augmented reality in improving the mathematical thinking skills of the intermediate students. The members in the experimental group enjoyed a high level of mathematical thinking skills, including the dimensions of deduction, induction, symbolic expression, modeling, and mathematical proof. What the program has brought about could be attributed to its activities and events and denial of the traditional method. The sessions in which activities, techniques and situations prepared from actual reality and all that is preferred and desirable interestingly and enjoyably were used helped facilitate the understanding and absorption of the scientific material, in addition to its focus on each mathematical thinking skill and their handling of all aspects of cognitive, emotional, social and motor development. The significance level of the students' deduction skills increased after training on the program. This result suggests that the students could derive the engineering rules related to the sixth chapter through AR. They enjoyed the experience of exploring geometric shapes and sizes. The significance level of the students' deduction skills increased after training on the program. The improvement in induction, symbolic expression, mathematical proof, and modeling skills could be attributed to the students benefiting from the training program based on augmented reality.

Recommendations

In light of the results ensued from the present study, some recommendations are put forward, and they could contribute to the promotion of using augmented reality in the mathematics curriculum for the intermediate stage in the following ways:

1. Familiarizing the teachers-in-training with the augmented reality and its impact on their knowledge.
2. Re-considering the design of teaching methods for different subjects in general and mathematics in particular. Revising such methods may include adding augmented reality technologies to enhance students' thinking skills in different areas of life. AR could be used as a successful method of education.
3. Organizing training courses for male and female teachers on the importance of (a) using AR at all stages and (b) developing and employing this mode of technology integration.
4. Motivating male and female teachers to learn and employ technology, namely the augmented reality in the educational process.
5. Researching and foreseeing the future of emerging technologies.

References

[1] Azuma, R. T. (1997). A survey of augmented reality. Presence: teleoperators & virtual environments, 6(4), 355-385.

[2] Al-Dahasi, A. A. (2017). Using augmented reality in developing mathematical thinking skills. Reading and Knowledge Journal (190), 90-112.

[3] Shezawiya, L. M. A. (2018). The effect of teaching based on augmented reality in acquiring the concepts of polygons and circles and in spatial inference among sixth-grade students [unpublished Master's thesis]. Sultan Qaboos University.

[4] Al-Ghamdi, I. A. M. (2018). The effect of using augmented reality on the mathematics achievement of middle school students. International Journal of Educational and Psychological Sciences, (13), 222-289.

[5] A'l Abdul-Jabbar, B. S. O. (2018). The effectiveness of augmented reality in developing scientific thinking skills in the science course at the primary stage (MA thesis). Imam Muhammad bin Saud Islamic University.

[6] Qahouf, S. A. E. & Abdel-Rahman, S. A. A. (2019). The interaction between the 'fixed/moving' virtual object and the augmented reality environment in the textbook context and the 'impulsive/educational' style impact learning survival and achievement motivation among middle school students in Sharurah Governorate. Journal of the College of Education, 35 (7), 696-752.

[7] Al-Qarala, M. F. (2019). The selective model's effectiveness in achievement and mathematical thinking in mathematics among eighth-grade students (Unpublished MA thesis), Mutah University.

[8] Radu, I. (2012, November). Why should my students use AR? A comparative review of the educational impacts of augmented-reality. In 2012 IEEE International Symposium on Mixed and Augmented Reality (ISMAR) (pp. 313-314). IEEE.

[9] Yuen, S. C. Y., Yaoyuneyong, G., & Johnson, E. (2011). Augmented reality: An overview and five directions for AR in education. Journal of Educational Technology Development and Exchange (JETDE), 4 (1), 11.

[10] Abu Hatab, F. A. & Sadiq, A. A. M. (2000). Educational Psychology (6th ed.). Anglo-Egyptian Library.

[11] Rizk, H. A. A. (2018). The effect of real learning on developing mathematical thinking skills for middle school students in Makkah Al Mukarramah. Journal of the College of Education, 180 (2.1), 354-384.

[12] Al-Biladi, H. H.A. (2019). The effectiveness of using a proposed strategy based on constructivist learning in teaching mathematics in developing mathematical thinking for first-grade intermediate students. Educational Journal, 62, 51-82.

[13] Al-Jaafari, A. M. H. (2019). A proposed strategy based on successful intelligence for teaching mathematics and its impact on developing sixth-grade students' mathematical thinking skills. Journal of the College of Education, 35 (8), 75-106.

[14] Matloob, A. A. M. (2019). The effect of using the Ady and Shire model on academic achievement and mathematical thinking among second-grade middle school students in Anbar Governorate in Iraq (Unpublished MA thesis). A'l Al-Bayt University.

[15] Al-Raheel, D. H. A. (2019). The effectiveness of blended learning based on electronic games in improving the achievement and mathematical thinking of the fourth-grade students and their attitudes towards it [Unpublished Ph.D. disertaion],Yarmouk University.

[16] Abu Jazar, K. M. M. (2018). The effect of employing the SUM strategy in developing the mathematical thinking skills of the ninth-grade students in Rafah governorate (Unpublished MA thesis). The Islamic University, Gaza.

Ali Alqarni: received the B.E. from Teacher College in Jeddah in 2004, and M.E. degree from Umm Al-Qura Univ. in 2010. He received the PhD. from Southern Illinois Univ. in 2016. After working as a computer teacher from 2005 to 2010, an assistant professor (from 2016) in the Dept. of Curriculum and Instruction, Umm Al-Qura Univ., he has been an associate professor at Umm Al-Qura Univ. since 2020. His research interest includes educational technology, e-learning, using computer in education.