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Mini Review

Impact of a Proposed Remedial Computerized Augmented Reality Program on Students' Performance in Mathematics Courses at Umm Al-Qura University*

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Abstract

The study aimed to shed light on the effects of a remedial program built around computerized augmented reality on students' conceptual knowledge in the Real Analysis Course. Adopting an experimental research design, 22 students in the Department of Mathematics at Umm Al-Qura University were recruited to take part in the study. A conceptual test was administered before the experiment, the remedial program was implemented, and a post-test was administered. The results showed a statistically significant effect of the proposed program on the participants' conceptual knowledge in terms of (i) mathematical concept recognition, (ii) the characteristics of concepts, (iii) interdependence and integration between concepts, and (iv) linking concepts to real life. Based on the findings, the study recommends training faculty members in augmented reality programs in teaching mathematics and preparing manuals for teaching mathematics via computer-augmented reality.

Introduction

Mathematics is undoubtedly one of the main pillars of scientific and technological growth. Technological advances in modern life have made familiarity with mathematical concepts and their various applications in public life a critical aspect of education. Such education enhances individuals' thinking, understanding, and creativity, as well as the assimilation of multiple discoveries in various fields of life. In teaching and learning, mathematics is synthesized from simple to complex concepts based on axioms used to derive results and theories through inferential steps governed by the laws of logic. It is also a field of research that draws on logic and cognitive thinking using promptitude, imagination, and accurate observation.

The National Council of Teachers of Mathematics (NCTM) stresses the importance of criteria for mathematics curricula based on five objectives: (i) realizing the value of mathematics, (ii) confidence in self-ability, (iii) having the ability to solve mathematical problems, (iv) mathematical communication skills, (v) and learning mathematical thinking. These elements improve students' ability to reason and think mathematically. They also provide learners with a valuable base in mathematical knowledge and skills [1,2]. According to the NCTM's [1] "Principles and Standards for School Mathematics", the primary goal of teaching mathematics is to ensure understanding by requiring learners to apply information in daily-life situations. To this end, classroom practice should focus on what learners do when learning mathematics.

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Conceptual understanding is construed as the basis of mathematical construction. It includes identifying mathematical concepts and characteristics, as well as grasping ideas and their relationships in different contexts. It also entails recognizing interdependence and integration with other concepts, finding logical justifications, and linking constructs to life. This helps learners add new concepts and experiences to their prior knowledge. The additional knowledge is internalized, represented, and harmonized to develop knowledge structures or correct previous knowledge. Thus, learners develop the skills to generate mathematical knowledge, solve unfamiliar problems, enhance their thinking methods, and engage in creativity. Moreover, the growth and support for the productive desire to learn mathematics, including positive attitudes and beliefs, passion, and motivation, is generally reflected in the learners' overall mathematic performance, which requires procedural fluency, strategic adequacy, and adaptive reasoning [3-8]. The NCTM Principles and Standards for School Mathematics include the principle of confidence, which refers to the use of mathematics schools teaching English [9].

According to Anderson, Love, and Tsai [10], the integration of digital technology in the learning environment has become inevitable due to rapid developments in recent times. Advances in information technology have led to enhancements in remedial approaches in education, including the use of complex digital learning environments, web-based learning, mobile learning, and computer-assisted collaborative learning. To increase scientific achievement, Firat, Koksal, and Bahsi [11] suggest that cognitive methods should be employed in teaching and learning that are based on the choice of appropriate technologies and the organization of learning environments based on such methods. Employing technology in teaching mathematics provides tangible opportunities to bring reality closer to the students' thinking and application of understanding. It provides an interactive environment that stimulates their imagination and helps them acquire thinking skills, thus resulting in deeper learning. This increases their academic achievement, improves their motivation to learn and creates positive attitudes toward mathematics.

In this regard, computerized augmented reality is proposed as one of the most important technological applications. It enables the integration of reality with virtual reality via specific Apps. These Apps allow the addition of digital data based on images, graphics, sounds, video, and simulations, which are installed using digital presentation methods. The use of such Apps aims to enhance the learning process, improve understanding, and increase the learners' motivation. Learners can experiment and explore within the learning environment [12,13].

In mathematics, computerized augmented reality simulates certain concepts or theories. It may also help learners deduce rules and correct misconceptions, for example concerning graphs and geometric shapes. Likewise, it may help them understand the differences between concepts, such as two-dimensional and three-dimensional shapes. Moreover, it trains them to solve various problems. The advantages and benefits offered by such technology all aim to help learners attain high performance and accuracy in mathematics learning and develop positive attitudes toward mathematics [14,15].

Many studies have recommended applying computerized augmented reality in teaching mathematics. For instance, Jawdah [16] reported the effectiveness of augmented reality in developing mathematical problem-solving skills and emotional intelligence among students with learning disabilities. Al Shizawiya [17] argued the effectiveness of teaching based on augmented reality in developing the acquisition of mathematical concepts and spatial reasoning based on research among sixth-grade female students. Similarly, Chen [18] showed that augmented reality can provide students with exciting visual experiences, in particular helping those suffering from severe anxiety toward mathematics; as a result, they excelled in algebra and geometry. Bhagat, Yang, Cheng, Zhang, and Liou [19] found augmented reality helpful in studying complex and abstract concepts as it allowed the students to apply them to three-dimensional geometric concepts. Demitriadou et al. [15] showed that augmented reality improved students' interaction and interest in the fourth, fifth, and sixth grades of primary school in learning mathematics, as well as developing their spatial ability.

In the context of this study, the researchers found that many mathematics students at Umm Al-Qura University are low achievers and perform poorly, and some even decide to quit certain scientific subjects because of the mathematics courses. The methods used to teach mathematical knowledge need to enable students to visualize mathematical concepts and develop thinking skills. Hence, it is necessary to move away from traditional teaching methods in mathematics to suit the nature of university level studies. Computer-enabled augmented reality is an essential part of initiating this change because it has repeatedly been hailed as an interactive educational environment that helps integrate real and virtual reality, thus contributing to mathematical knowledge and its association with the real world in learners' minds. This motivated the researchers to conduct the study to explore the impact of a proposed treatment program based on computerized augmented reality. The program aimed to improve conceptual understanding through real analysis among mathematics students at Umm Al-Qura University. The study addressed the following question:

What is the effect of a proposed remedial program based on computerized augmented reality on identifying mathematical concepts, the characteristics of concepts, the interdependence and integration between concepts, and the connection to life among mathematics students at Umm Al-Qura University?

Study Objectives

The study aimed to determine the effect of a suggested remedial program based on computerized augmented reality on the conceptual knowledge of mathematics students at Umm Al-Qura University.

Significance of the Study

The findings offer planners of the mathematics curricula at the university with new information and a vision commensurate with ongoing technical development in the current era, harnessing

computerized augmented reality in the design and implementation of mathematics courses. The study may help faculty members address the difficulties some students face in understanding mathematical conceptual and procedural knowledge.

Scope of the Study

The study was limited to measuring conceptual assimilation in the following dimensions: identifying mathematical concepts, identifying the properties of concepts, recognizing interdependence and integration between concepts, and linking to life in the Real Analysis course. It was applied to a sample of Umm Al-Qura University students during the summer semester of the 2022 academic year.

Key Terms

Augmented Reality

Augmented reality is technology that integrates virtual objects and real-world environments through text, images, scenery, 3D shapes, video, etc., in an accurate and meaningful way, allowing students to immerse themselves and interact in real time with integrated mathematical content.

Conceptual Assimilation

Conceptual assimilation includes four dimensions, as follows:

1. Identify the mathematical concept by naming the concept using different expressions or representations or symbols, shapes and images and giving examples of belonging and not belonging to the mathematical concept.

2. Identify the characteristics of the mathematical concept by describing and classifying the mathematical concept in light of its characteristics, identifying the similarities and differences between the mathematical concept and other concepts, and identifying the characteristics that belong to the concept and do not belong to it.

3. Determine the interdependence and integration between mathematical concepts by defining the relationships between them, identifying the perceptual change of the concept, and building diagrammatic forms of the relations between concepts.

4. Link to life using the mathematical concept in various new applied contexts, giving examples of the concept based on real-life situations.

Method

A semi-experimental method was used based on a pre-test/post-test design with one group of learners.

Population and Sampling

The study population of all the students attending the Real Analysis course in the Department of Mathematics at Umm Al-Qura University. The study recruited 22 students who were sampled randomly.

Augmented Reality-Based Program

Based on the literature review, previous relevant studies, and similar programs relevant to computer-enhanced reality, a program was developed for the Real Analysis course. The topics appropriate for the tasks in the educational experiment were identified. The appropriateness of the program was checked with arbitrators to ensure it suited the educational situation under scrutiny and make any necessary amendments based on their feedback.

Data Collection

In light of the study objectives, a conceptual assimilation test was prepared. The dimensions of the conceptual knowledge in question and their indicators were identified. The questions corresponding to each indicator were designed and presented to arbitrators to ensure the correctness and integrity of the scientific and linguistic formulation for all items. Appropriate modifications were made based on their feedback: only 20 items of the multiple-choice type were fine-tuned. The test was piloted with a sample of 12 students. Reliability calculated using the Kuder-Richardson Formula 20 gave a coefficient of 0.86, indicating good reliability and the test was thus suitable for use in the investigation.

Table 1: Results of t-tests showing the difference between pre-test and post-test scores for the four dimensions.

Domain	Group	N	Mean	Std. Dev.	t	df	Sig
Identify mathematical concepts	Pre-test	22	2.22	0.795	0.149	21	0.041
	Post-test	22	2.77	1.307			
Identify the properties of concepts	Pre-test	22	2.14	1.39	2.768	21	0.006
	Post-test	22	3.09	1.342			
Determine interdependence and integration between concepts	Pre-test	22	3.36	1.136	1.936	21	0.033
	Post-test	22	3.82	1.332			
Make connections to real life	Pre-test	22	2.18	0.907	2.16	21	0.021
	Post-test	22	2.55	0.671			
Total	Pre-test	22	10.5	2.773	2.385	21	0.013
	Post-test	22	12.23	3.753			

Results

To answer the research question (see Introduction), a t-test (paired samples) was used to examine the significance of differences between the mean pre- and post-test scores on the four dimensions of the conceptual comprehension test. The results are presented in Table 1. As can be seen, the t-values are statistically significant at the level of $\alpha \leq 0.05$. This indicates the existence of statistically significant differences between the pre- and post-test mean scores of the sample for all four dimensions: mathematical concept recognition, identifying the properties of concepts, recognizing the interdependence and integration between concepts, and making connections with life. All the results are in favor of the post-test. This indicates that the computer-based augmented reality program improved students' performance on conceptual assimilation as a whole.

These results are consistent with those of some previous studies. For instance, Al-Shezawiya [17] reported the effectiveness of teaching based on augmented reality in developing mathematical concepts and spatial reasoning among sixth-grade students. Likewise, Chen [18] concluded that augmented reality reduced students' anxiety and made them excel in algebra and geometry. Bhagat et al. [19] found that augmented reality technology helped students attain complex and abstract concepts through applying them to learning three-dimensional engineering concepts. Demitriadou, Stavroulia, and Lanitis, [15] also showed that augmented reality technology improved the learning and understanding of fourth, fifth, and sixth-grade students of mathematical concepts. Further, Ozcakir and Cakiroglu [20] concluded that augmented reality technology helped improve student achievement in mathematics.

This study argues that the improvement in conceptual knowledge can be attributed to the experimental treatment in the following respects:

1. The augmented reality simulated some mathematical concepts and provided students with visualizations of the structures and components of things in the natural environment. It also helped correct some misconceptions through the tasks and educational activities it provided. It helped achieve integration between mathematics and technology and enhanced students' comprehension in identifying mathematical concepts, the properties of concepts, the interdependence and integration between concepts, and linking mathematical concepts to life.

2. The augmented reality mode provided a realistic interactive environment and opportunities for self-learning. It helped students organize and analyze the components of mathematical content, realize the relationships, transformations, and vertical and horizontal interconnections between the elements. Moreover, the students could identify the characteristics of the content and build different representations; this applied approach contrasts with the traditional memorization of mathematical facts, concepts, and principles. Meaningful and linked to real life, the use of augmented reality thus positively contributed to students' conceptual understanding.

Recommendations

1. Training should be provided for faculty members in the use of computer augmented reality in teaching mathematics courses.

2. Guides should be prepared for faculty members to aid them in teaching mathematics courses using computerized augmented reality technology.

Acknowledgment

None.

Conflict of Interest

No conflict of interest.

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