Effectiveness of Augmented Reality Content on Visual Thinking in Mathematics among Secondary School Students

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Abstract

Augmented Reality Content is the computer-generated input used to enhance parts of learner's physical world through mobile, tablet or smart glasses. This research aimed to identify the Effectiveness of Augmented Reality Content on Visual Thinking in Mathematics among Secondary School Students. To accomplish the research objective, the experimental method with a non- equivalent group design was adopted and it included an experimental group and a control group with the pre-test and post-test of both groups. The research was implemented on a random sample of 68 students and the research tools included the Visual Thinking Test, Lesson Transcripts based on Augmented Reality Content and Lesson Transcripts based on Activity-Oriented Method. The tools were pre- and post- tested to the ninth standard students of the academic year 2022. The results concluded that the experimental group surpassed the control group in visual thinking. Based on the results, the researcher recommended the involvement of augmented reality content in mathematics instruction at different levels of education.

Keywords: Effectiveness, Augmented Reality Content, Secondary School, Mathematics, Visual Thinking in Mathematics.

Introduction

AR Content is information that is relevant to a certain location, also called a point-of-interest (POI). (Visser, 2011). Augmented Reality is an area of research that aims to enhance the real world by overlaying digital information on top of it. AR applications enrich the perception of the context and it is a new way to interact with information. Augmented Reality can help to supply information in a context with limited information and enhance user experience. The creation of Augmented Reality Content can potentiate the integration of social media (Vera, 2016).

According to the National Council of Teachers of Mathematics [NCTM](2015), technology use is essential for developing learner's mathematical skills, encouraging them to learn more profoundly and increasing their interest in Mathematics. The Augmented Reality Content helps students to understand complex subjects by providing 3D simulations of invisible situations that are hard to visualize (Cai et al., 2020). Visual Thinking in

Mathematics is defined as the mental activity and skill that involves visual imagination or visual perception of external diagrams, is widespread in Mathematics, across levels, across subjects and across kinds of mathematical activity (Giaquinto, 2007). Augmented Reality Content has an effective role in developing thinking, especially visual thinking. Several studies have found that students who were taught with Augmented Reality Content performed significantly better than those who were not taught to them in achievement and visual thinking (Al-Ghamdi, 2020; Al Hilou, 2017; Al-Muqrin, 2020; Al-Salahat, 2019; Osamah et al., 2019; Salama, 2019).

The study titled "Effectiveness of Augmented Reality Content on Visual Thinking in Mathematics among Secondary School Students" is of great importance as it throws light into the extent to which AR Content enables learners to grasp abstract mathematical concepts and help them to create immersive educational experiences on their own, thereby enhancing the cognitive skills of the learners, especially Visual Thinking in Mathematics. The main goal of the paper was to prove the effectiveness of teaching Mathematics with Augmented Reality (AR) Content over Activity-Oriented Method in enhancing the Visual Thinking in Mathematics among Secondary School Students.

In the next sessions of the paper, the investigator will test the effectiveness of teaching Mathematics based on Augmented Reality Content over Activity-Oriented Method on Visual Thinking in Mathematics among Secondary School Students with reference to components of Visual Thinking as Visual Discrimination Skill, Scientific Deduction Skill, Visual Reading Skill and Skill of analyzing and interpreting the visual shape.

Need and Significance of the study

The advancement and popularity of handheld devices and sensing technologies has enabled researchers to implement more effective learning methods (Ogata, Li, Hou, Uosaki, El-Bishouty, & Yano, 2011). Most of mobile learning studies emphasize the adoption of digital learning aids in real-life scenarios (Sharples, Milrad, Arnedillo- Sanchez, & Vavoula, 2009; Ogata & Yano, 2004; Wong & Looi, 2011). However, regarding supplementary mobile learning aids, the interaction between digital learning aids and the actual environment needs to be emphasized to enable students to effectively manage and incorporate personal knowledge (Wu, Lee, Chang, & Liang, 2013). Augmented Reality Content combines human senses (e.g., sight, sound and touch) with virtual objects to facilitate real-world environment interactions for users to achieve an authentic perception of the environment (Azuma, 1997).

The use of Augmented Reality Content in Mathematics allows the learner to experience virtual objects in another way without losing contact with the environment in which they are. According to a study by Orozo,

Esteban and Trefftz (2006), the learners who were taught Mathematics using Augmented Reality Content were able to infer generalizations, considering what they observed, and predict what would happen with the graphical representation of other functions. The learners also showed greater ease in understanding the mathematical concepts taught. Augmented Reality Content in Mathematics contributes to increased understanding of mathematics content, in particular learning geometry and 3D shape.

Augmented Reality Content reinforces the teaching and learning process, and encourage learners to pursue tasks. Also, AR Content develops positive trends towards learning mathematics. By incorporating Augmented Reality Content in teaching Mathematics, students may improve visual thinking by focusing on the shapes, sketches and images provided in the situation and the actual relationships involved in it, and trying to find meaning for the material they contain (Campbell et al., 1995).

Ahmad (2020) also mentioned that the benefits of Augmented Reality Content in Mathematics learning are that these content increases learner's confidence and understanding. It contributes to increased understanding of mathematics content, in particular learning geometry and 3D shape. The Augmented Reality Content improves the geometry visualization of learners by providing interesting and entertaining visual content to see engineering objects from different angles and this made learning Mathematics more effective.

Sun and Chen (2019) in the article "Utilizing free augmented reality app for learning geometry at elementary school in Taiwan: Take volumetric measurement of compound body for example" studied on Augmented Reality Content in Mathematics education and observed that AR Content positively affected interaction besides encouraging students to participate in learning activities with less cognitive effort and enhance their learning performance.

Estapa and Nadolny (2015) conducted a study examining the effect of Augmented Reality Content on the success and motivation of students in a Mathematics lesson, they found that AR Content had a positive impact on the success and motivation of students. Studies were conducted on the benefits of Augmented Reality Content in facilitating the mathematics learning (Ahmad, 2020., Sun and Chen, 2019., Estapa and Nadolny, 2015).

The effect of Augmented Reality Content on Mathematics learning especially learning geometry and 3D shape (Orozo, Esteban and Trefftz, 2006) were also conducted. These studies prove that the effective intervention of Augmented Reality Content in Mathematics can improve learner's confidence and understanding in

Mathematics. But, from the review conducted in the related field, it is clear that no studies were conducted to find the effectiveness of Augmented Reality Content on Visual Thinking in Mathematics of Secondary School Students. So, the investigator made efforts to integrate Augmented Reality Content in the teaching of Mathematics and developing visual thinking skills in students by focusing on the shapes, sketches and images provided in the situation and the actual relationships involved in it, and trying to find meaning for the material they contain.

Incorporating Augmented Reality Content in teaching Mathematics will enhance the visualization skills of students and contributes to increased understanding of Mathematics content, in particular, learning geometry and 3D shapes. Learners are able to visualize the mathematical concepts in a broad spectrum by the use of AR Content in teaching Mathematics.

Visual Thinking plays an imperative role in mathematical problem-solving. The learning experiences become more meaningful when more senses are involved. The use of Augmented Reality Content in classroom fosters the understanding of abstract mathematical concepts. Visual images or diagrams may illustrate causes of a definition, thereby giving learners a more vivid grasp of its applications. The visual images play an extremely important role in the thinking and learning of Mathematics.

The study is expected to induce conscious efforts and techniques by authorities in the field to help student's meet mathematics-related goals. On the basis of above consideration, it was found necessary that a study incorporating Augmented Reality Content in Mathematics be undertaken.

Objective of the Study

- To test the effectiveness of Augmented Reality Content on Visual Thinking in Mathematics among Secondary School Students for the total sample.

Hypothesis of the Study

- There will be significant difference between the students taught using Augmented Reality Content and Activity-Oriented Method on Visual Thinking in Mathematics among Secondary School Students for the total sample.

Methodology

An experimental study with pre-test post-test non-equivalent group design was used for present study. The variables selected for the present study was teaching using Augmented Reality Content and Activity-Oriented Method as independent variables and Visual Thinking in Mathematics as dependent variable.

A sample of 68 secondary school students was selected for the study using simple random sampling technique. A Visual Thinking Test was used for collection of relevant data from the sample.

Analysis and Interpretation of Data

Objective

To test the effectiveness of Augmented Reality Content on Visual Thinking in Mathematics among Secondary School Students for the total sample

Table 1

Descriptive Statistics of pre-test and post-test scores of Experimental and Control groups on Visual Thinking Test

Groups		Mean	Median	Mode	Standard deviation	Skewness	Kurtosis
Experimental	Pre-test	6.629	6	7	2.635	0.633	-0.266
	Post-test	11.6	11	11	4.391	0.414	0.740
Control	Pre-test	8.667	9	8	2.314	0.305	0.321
	Post-test	9	9	9	2.973	0.118	-1.029

From the Table 1, it is clear that the arithmetic mean, median and mode for the pre-test scores of Control Group and Experimental Group are almost the same. Standard deviation values also indicate that the sample is almost homogeneous with regard to the pre-test and post-test scores on Visual Thinking Test. The distribution is positively skewed for pre-test of Experimental Group. This means that the scores are massed at the lower end of the distribution. The kurtosis value is greater than 0.263 for post-test of Experimental and pre-test of Control Group. Hence the distribution is platykurtic. The kurtosis value is less than 0.263 for pre-test of Experimental and post-test of Control Group meaning that the distribution is leptokurtic.

Figure 1

Bar diagram representing mean values of the pre-test and post-test scores of Experimental and Control groups on Visual Thinking Test

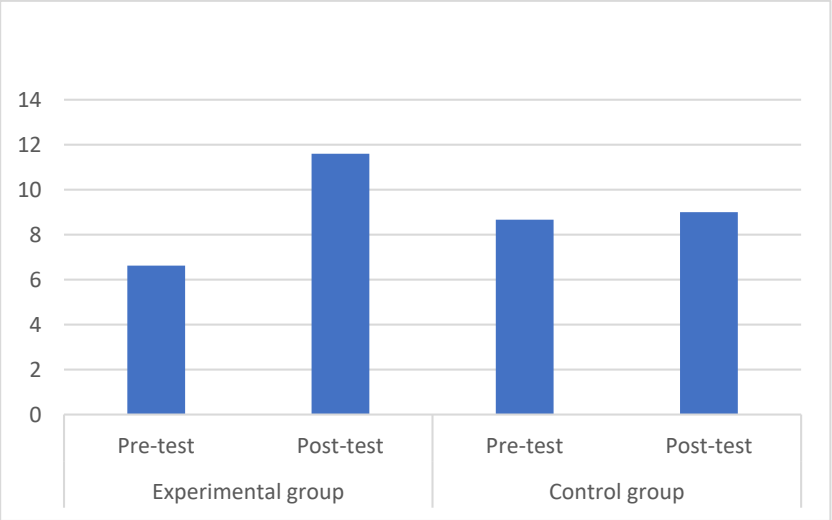


Table 2

Comparison of Pre-test scores of Experimental and Control groups on Visual Thinking Test

Groups	N	Mean (M)	Standard Deviation (SD)	t-value
Experimental	35	6.629	2.635	0.764
Control	33	8.667	2.314	

The t-value obtained is not significant at 0.01 level. This shows that there is no significant difference between the means of Pre-test scores of learners in the Experimental and Control groups before the treatment.

Figure 2

Bar diagram representing mean values of Pre-test scores of Experimental and Control groups on Visual Thinking Test

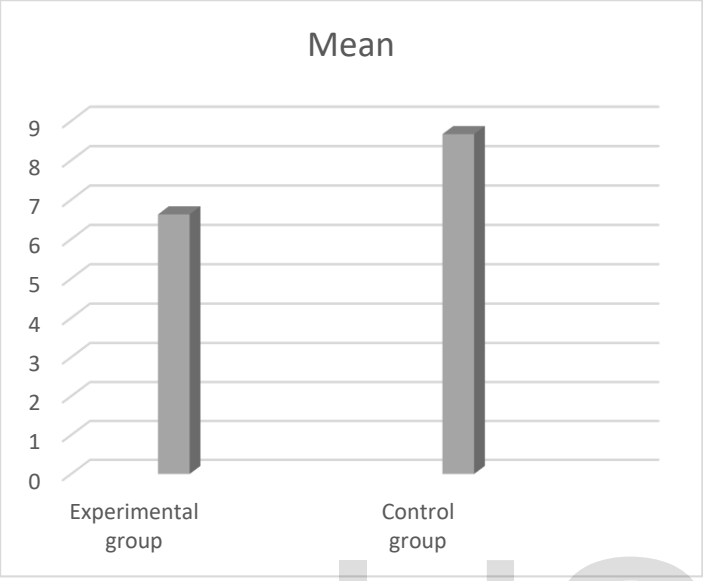


Table 3

Comparison of Post-test scores of Experimental and Control groups on Visual Thinking Test

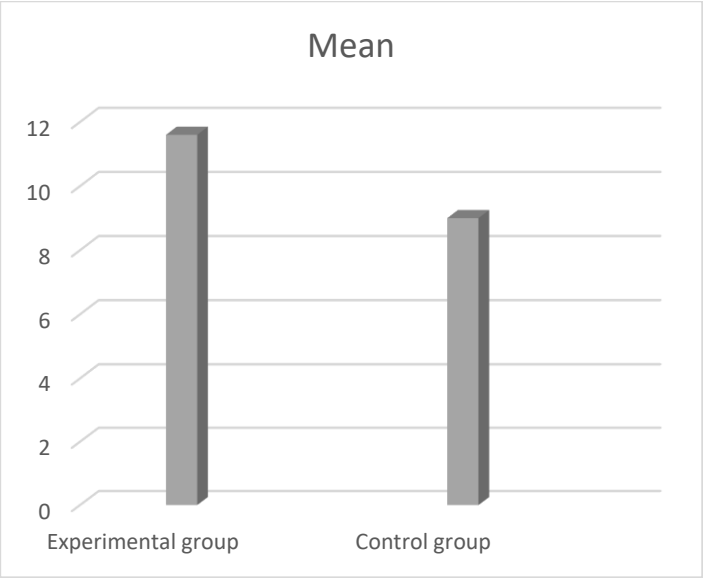
Groups	N	Mean (M)	Standard deviation (SD)	t-value
Experimental	30	11.6	4.39	3.24^{**}
Control	32	9	2.97	

***significant at 0.01 level*

From Table 3, it is clear that the t-value obtained ($t=3.24$; $p<0.01$) is significant at 0.01 level. This means that there is significant difference between the means of Post-test Visual Thinking Test scores of learners in the Experimental and Control groups. This means that the two groups differ significantly after the treatment.

Figure 3

Bar diagram representing mean values of Post-test scores of Experimental and Control groups on Visual Thinking Test



Educational Implications of the Study

The Educational Implications emerged from the results of the study are presented below:

The results of the study revealed that teaching based on Augmented Reality Content is effective than Activity-Oriented Method of teaching for Visual Thinking in Mathematics of students at secondary school level when the total sample is considered. The finding has implications in the following areas**.**

Learners

The use of Augmented Reality in Mathematics education supported learning and motivation and enhanced the spatial abilities of students. The effective implementation of Augmented Reality into the class must be encouraged as AR Content can promote interactive learning experiences with coursework, encourage collaboration between students, improve motivation, and increase learning gains. By integrating AR Content as a support to the teaching-learning of mathematical functions, students can explore and develop cognitive schemes that enhance proactive self-learning by achieving a progression in the development of analysis, application, reflection, and interpretation of knowledge. Augmented Reality Content in Mathematics favours the creation of a constructivist and realistic learning context and enhances the Visual Thinking of students, which is a fundamental aspect of understanding, constructing mathematical concepts.

Teachers

Teachers are the common element in every educational system and play a key role in the integration and acceptance of technology in education. Teachers should be given an orientation to the use of AR Content in classrooms as AR

technology enables teachers to create immersive educational experiences on their own to help ensure their students understand curriculum content. AR Content creates opportunities for teachers to help students grasp abstract concepts. By using the interaction and experimentation that AR technologies offer, teachers can enhance classroom experiences, teach new skills, inspire student minds, and get students excited about exploring new academic interests. The use of AR Content enables teachers to show virtual examples of concepts and add gaming elements to provide textbook material support.

Curriculum planners

The curriculum designers should plan the teaching-learning process incorporating the use of AR technology in classrooms as AR technologies offer interaction and experimentation in classrooms and thereby enhance new skills and classroom experiences, inspire student minds, and get students excited about exploring new academic interests. The curriculum must be designed in such a way that students engage actively in the learning process by incorporating AR Content in every discipline of study.

Teacher Education Programmes

Ongoing technology progress sustains innovative teaching approaches. In Teacher Education AR can play a constructive role in different areas of study, but always in accordance with the premise of TPCK (Technological Pedagogical Content Knowledge). The educational approaches, when combined with emerging augmented reality (AR) technologies, can enhance learning experiences, as they can

enrich and contextualize learning information offered to learners. The incorporation of AR into educational practices for effective learning requires teacher training in teaching methodologies with AR technologies.

Technological Pedagogical Content Knowledge (TPCK) is essential for teacher to successfully implement AR Content within classrooms. In teacher-training, the Learning Technology by Design approach is suggested, which confronts teachers in their training with authentic pedagogical problems. Learning Technology by Design approach can be used within an in-service teacher-training course about classroom implementation of AR.

Conclusion

This research aimed at identifying the impact of the use of the Augmented Reality Content when teaching Mathematics in the development of Visual Thinking among secondary school students, using the experimental approach and a pre-test post-test non-equivalent group design. When analyzing results, it became clear that the students of the experimental group exceeded the students of the control group in Visual Thinking, as the Augmented Reality Technology adapted the actual reality through adding digital features to improve the perception of the learner.

The use of the Augmented Reality Technology when presenting the skill side by side with its details achieved better learning than the conventional way and enhanced the development of the visual thinking skills.

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