Research Article

Understanding the potential of Augmented Reality to improve Mathematical Education

Meenakshi P.K[1], Indu.H[2]

[1]Research Scholar, Department of Education , Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamilnadu

Email- 18phedp004@avinuty.ac.in

[2]Deputy Dean & Professor, Department of Education , Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, Tamilnadu

Abstract

Since Augmented Reality (AR) has the potential to completely transform conventional teaching methods, it is highly significant in the field of mathematics education. Its ability to enhance visualization by providing dynamic and interactive representations of complex mathematical ideas is one of its main advantages. The purpose of the study is to evaluate their awareness and attitude toward the use of AR in math education. The study employed the descriptive survey method. 122 upper primary mathematics teachers from the Coimbatore district are the subjects of the current study. There were 66 female and 56 male math teachers in the study sample. Therefore, based on mean scores, there is no discernible difference in the Awareness score between gender, years of experience, and educational attainment. While there is no discernible difference in years of experience or educational attainment, there is a significant gender difference when looking at the Attitude score. The study's conclusions point to a possible paradigm change in instructional strategies as AR becomes a game-changing tool for improving student learning. Additionally, the study suggests that curriculum modifications are necessary to smoothly integrate AR and bring instructional materials into line with the quickly changing technology environment.

Keywords: Augmented Reality, Mathematics Education, school teachers, Awareness and Attitude

Introduction

Mathematics is a crucial tool in everyday life, influencing our activities and decisions (Manjunath, 2021). It is essential for problem-solving, creativity, and critical thinking, and is used in various fields, including science, engineering, and economics (Peter, 2011). Mathematical literacy, which includes competencies such as mathematical thinking and reasoning, is a key skill for navigating the complexities of the 21st century (Rizki, 2019). Despite its importance, many students struggle to see the real-life applications of mathematics, and it is often perceived as a dry and irrelevant subject (Manjunath,2021). The fundamental mathematical operations—addition, subtraction, multiplication, division, and certain geometrical shapes—have a great deal of application in everyday life (Devlin, 2005). The development of mathematical knowledge and abilities in schools depends on the methodical and efficient teaching of mathematics (Târnoveanu, 2017) . This involves using various teaching methods tailored to the learning abilities of students (Yanushkevichiene, 2016). Since mathematics is crucial for both academic performance and problem-solving, it is

necessary to foster a favorable attitude toward it (Târnoveanu, 2017).

Attitudes, as defined by Zanna and Rempel (1988), are complex psychological constructs influenced by affect, cognition, and individual differences (Haddock, 1993). This inclusive definition, proposed by Eagly (2007). Maio (2013) emphasizes the evaluative nature of attitudes and their role in shaping behaviour. Further explores the link between attitudes and behaviour, highlighting their unique psychological content, structure, and function. However, Wicker (1969) raises a critical question about the relationship between attitudes and behaviour, suggesting that the two may not always align. It involves a combination of cognitive, affective, and behavioural components that shape how individuals perceive and respond to the world around them (Eagly,et al., 1993). This study examines attitudes toward the use of augmented reality (AR) in math instruction, both favourable and negative.It influences a teacher's behaviour or utilizing AR in teaching Mathematics favourably or unfavourably. The condition of knowing something is called awareness by (Baars, B. J.1997). According to the current study, awareness is the condition of being educated about integrating the use of augmented reality into math instruction. AR is a technology that allows users to interact with virtual objects superimposed on real-time visuals (Azuma R 1997 & 1999). Augmented reality (AR) overlays digital information on real-time photographs to create an interactive and dynamic environment (Milgram et al., 2013).

Augmented Reality (AR) provides a platform for teaching abstract concepts that are hard to visualize mentally, as suggested by (Kaufmann 2003) ; (Núñez et al., 2008); (Shelton et al., 2002), and (Wu et al., 2013). AR leverages multimedia elements like texts, pictures, audio, and video, along with 3D models (Shelton et al., 2002), to enhance the learning experience. Some of the studies conducted in teaching Mathematics of Geometric objects (İbili ,2013) , Prisms (Tosik Gün, et al., 2017) Geometric objects (İbili et al.,2013) & (Tosik Gün, et al., 2017) using AR.

Need and Significance of the Study

Any child has to learn mathematics to be able to use their skills and knowledge in a variety of contexts. Mathematical qualification plays a significant role in the curriculum as it is one of the defining features of scientific culture (Kothari Commission, 1986).

Developing logical and problem-solving abilities among children is the major objective of teaching Mathematics as the development of children's ability for Mathematization i.e. students' thought processes must be mathematized (NCF, 2005). The study of mathematics enhances one's capacity to solve problems and think critically, creatively, and logically, which has an enormous impact on every day life(Sharma, 2021; Dahiya, 2014). These are adaptable talents that are essential in a variety of fields (Evans, 2000).

Mathematics is not only relevant in the workplace but also in daily life, where it is used in a wide range of activities (Yeo, 2010). In this sense, mathematics is one of the basic disciplines taught in schools, and many pedagogical approaches are used to raise students' mathematical success levels. (Gervasoni, 2008) emphasizes the need for successful mathematics pedagogy, while (Chen, 2020) focuses on the integration of subject knowledge and information technology in high school mathematics education. (Pokharel, 2020) highlights the importance of innovative activities, worksheets, and teaching aids in making mathematics learning joyful and effective. (Chaman,

2014) underscores the significance of mathematical knowledge and competence in secondary school education. Despite having implemented various teaching strategies to teach Mathematics, the slow learners couldn't achieve the expected attainment. This is because the learners couldn't imagine their concepts. In this regard, slow learners find it difficult to make use of their abstract thinking. Slow learners often struggle with abstract thinking in mathematics, particularly in areas such as reflective abstraction, mathematical reasoning, and problem-solving strategies (Wafiqoh, 2022). To address this, specific measures and methods to cultivate their abstract thought ability. In the context of writing, slow learners face challenges in narrative text due to their limited abstract thinking (Husain, 2020). This is further compounded by difficulties in understanding mathematical concepts and performing arithmetic operations (Metikasari, 2019). To overcome these challenges, it is important to provide clear conceptions and use teaching aids to help slow learners understand and apply abstract concepts.

Generally, the Mathematics teachers stick with the chalk-and-talk method in which most of the mathematical problems are written on a Blackboard and explain the concepts orally by the teacher. To modify the teaching strategy and enhance the professionalism among the teachers by using Augmented Reality in teaching Mathematics. How for the Mathematics teacher have wider knowledge about Augmented Reality and to what extent does their attitude in utilizing Augmented Reality in teaching Mathematics?

Review of literature

It has been shown that integrating augmented reality (AR) into mathematics instruction promotes pupil understanding and engagement with the material. The potential of AR to increase motivation and comprehension, which will result in a deeper comprehension of concepts in mathematics, is being highlighted by (Buentello-Montoya, 2021) and (Coimbra, 2015) . The use of augmented reality (AR) to visualize mathematical objects and create a more relevant learning environment is discussed in (Yingprayoon, 2015) and (Carvalho, 2014), which lends greater weight to this. The considerable potential of augmented reality in mathematics teaching is highlighted in the literature research. Because it encourages motivation, collaboration, and real-world relevance, Augmented Reality (AR) has the potential to substantially enhance the mathematics learning experience (Coimbra, 2015; Kazanidis, 2019; Chao, 2018). It can promote a deeper comprehension of mathematical ideas, resulting in the absorption of information and the growth of persistent competencies (Coimbra, 2015).Enhancing learning results, augmented reality apps can also offer clear learning situations and more participatory encounters (Kazanidis, 2019). Moreover, AR has the potential to improve students' comprehension of mathematical ideas, especially when it comes to volume and 3D composition (Chao, 2018). The technology's capacity to combine the real and virtual worlds can help students grasp abstract ideas, enable embodied representations of mathematical ideas, and foster collaborative learning (Bujak et al., 2013). The use of AR in mathematics education presents both benefits—such as improved learning and motivation—and challenges—such as technical issues and resistance to new technology (Palancı, 2021). Despite these difficulties, AR and Virtual Reality (VR) technologies have been found to have potential benefits in mathematics learning, particularly in the areas of socio-emotional, cognitive/

meta-cognitive, and pedagogical development (Cevikbas, 2023). Teachers face difficulties in creating AR-assisted learning media, including conforming to hardware and software standards and gaining access to pertinent resources.

Statement of the Problem

Integrating Augmented Reality is the modern trend in teaching core subjects in schools for the academic excellence of the students as well as to enhance the professionalism of teachers. It is anticipated that all educators possess a strong attitude and awareness when it comes to using augmented reality in the teaching of mathematics. If so what extent is their Attitude and Awareness in integrating AR in teaching Mathematics? Hence the study is carried out by the researcher entitled "The Role of Augmented Reality in Enhancing Mathematics Education: A Study on Awareness and Attitude".

Objectives of the Study

To determine if the use of Augmented Reality (AR) in math instruction by upper primary teachers is significantly impacted by factors such as gender, years of experience, and educational background.

Research Questions

Do upper primary Mathematics teachers exhibit differences in their attitude and awareness of the integration of augmented reality in Mathematics instruction based on gender, educational qualifications, and years of experience?

Method

Research design: The study followed the descriptive survey approach. A descriptive survey design is a widely used method in research, particularly in social sciences, to describe characteristics of a population or phenomenon being studied. In this design, the researcher collects data without manipulating the environment. The goal is to gather quantifiable information to describe patterns, trends, or phenomena.

Population and Sample: The study's population consists of upper primary mathematics teachers in the Coimbatore area. The samples for the research were selected using a cluster sampling method. This method involves dividing the population into clusters (which could be based on schools or geographic areas), and then randomly selecting clusters for inclusion in the sample.56 male and 66 female teachers of mathematics from the Coimbatore district made up the samples. The study's sample includes 122 upper primary mathematics teachers in total.

Design and development of tools of study

Questionnaire: To evaluate Awareness and Attitude toward Augmented Reality in integrated mathematics instruction, the researcher has examined several earlier studies. It was discovered that no tools were accessible to measure Attitude and Awareness scales related to the incorporation of augmented reality in mathematics education. As a result, the researcher created two original instruments for the investigation.

- Attitude towards integrating Augmented Reality in teaching.
- Awareness of integrated Augmented Reality in teaching Mathematics

The researcher reviewed several literates and discussed with the subject experts the selection of items for the tools. The items of the two tools are arranged separately for Attitude and Awareness in integrating AR in teaching Mathematics. After drafting the English version of the items, the

same was translated into Tamil for easy understanding of the AR in integrated Mathematics teaching.

In the initial development of the tools for measuring Attitude and Awareness regarding the integration of Augmented Reality (AR) in teaching mathematics, a total of 43 items were selected for the attitude scale and 36 items for the awareness scale. These tools were designed to assess teachers' perspectives on AR and its application in mathematics education. Subject experts who are directly involved in mathematics teaching and have ICT experience at both school and college levels were consulted to review the tools. The experts were requested to provide their opinions and suggestions on various aspects, including the language, simplicity, relevance, and validity of the items in both tools.

Based on the feedback from the subject experts, the researcher made necessary modifications to improve the clarity and appropriateness of the statements. This process ensured that the tools were not only easy to understand but also aligned with the study's objectives. Both tools included closed-ended questions to systematically assess the participants' knowledge of AR and its practical application in integrating AR with mathematics teaching. These revisions helped ensure that the tools were valid measures of the teachers' attitudes and awareness regarding AR integration in mathematics classrooms.

Validity: The content validity of 2 tools was established in consulting with a team of 5 subject experts in the field of Mathematics who have experience in utilizing ICT teaching. They have analyzed the appropriateness of the items for the assessment.

Reliability: Thirty upper primary school teachers who were not engaged in the study were given the two tools as a sample. To test the consistency between the two sets, every item in each of the two tools is split into two equal halves at random. The Split-Half Method was employed by the researcher to determine the two tools' reliability. The study employed the alpha approach to determine each tool's internal consistency independently. The researcher rejects items in the two tools with alpha values less than 0.25 and larger than 0.80. There are 35 items in the attitude toward integrated augmented reliability in mathematics education scale, which is the last instrument.

The Pearson- Correlation was found for Attitude towards integrating AR in teaching Mathematics to be 0.89, and Awareness of integration of AR in teaching Mathematics was found to be 0.87. This indicates consistency between two sets with high reliability.

Scoring Procedure: The Attitude towards Augmented Reality in Teaching Mathematics Scale has a 5-point Likert type, with positive statements scoring 5 points and negative statements scoring 5 points. The Awareness of Augmented Reality in Teaching Mathematics Scale has a 3-point Likert scale, with no negative statements. The maximum score is 60, and the minimum is 0.

Results and Discussion

Do the upper primary Mathematics teachers differ in their Attitude and Awareness in integrating Augmented Reality in teaching Mathematics concerning their Gender, Educational qualifications and years of experience?

For testing the research question, the following results were found by the investigator.

Table-1: Attitude and Awareness result based on Gender

	Variable	N	Mean	S.D.	Levene's Test		t-test for Equality of Means		
					F	Sig.	t	Sig.	Result
Awareness score	Male	56	34.61	14.481	0.055	0.815	-0.488	0.626	NS
	Female	66	35.89	14.531					
Attitude score	Male	56	133.07	12.090	15.433	0	23.709	0	S
	Female	66	57.89	22.165					

Awareness Score: According to Levene's test, the equal variances assumption between the groups is confirmed with non-significant findings ($p = 0.815$). The null hypothesis cannot be rejected since there appears to be no discernible difference in Awareness scores, according to the t-test ($t = -0.488$, $p = 0.626$). As a result, there is no statistically significant difference between the two groups' mean Awareness ratings.

Attitude Score: For Attitude scores, Levene's test finds a violation of the equal variances assumption ($p < 0.001$). There is a considerable difference in the mean Attitude scores between the two groups, as indicated by the very significant p-value (0, almost zero) of the subsequent t-test that takes uneven variances into account. These results support the notion of uneven variances.

Table -2 : Attitude and Awareness result based on Educational status

	Variable	N	Mean	S.D.	Levene's Test		t-test for Equality of Means		
					F	Sig.	t	Sig.	Result
Awareness score	UG & B.Ed	73	36.01	14.709	0.059	0.808	0.666	0.507	NS
	PG B.Ed	49	34.24	14.171					
Attitude score	UG & B.Ed	73	88.63	42.128	0.000	0.983	-1.226	0.223	NS
	PG B.Ed	49	98.02	41.034					

Awareness Score: For equal variances assumed ($p = 0.808$) and not assumed ($p = 0.507$), both surpassing the 0.05 significance threshold, non-significant findings are shown by Levene's test for Awareness scores. This implies that both possibilities satisfy the premise of equal variances. When equal variances are not assumed, the t-test, taking uneven variances into account, confirms a non-significant p-value (0.507), showing no discernible difference in the mean Awareness ratings between the two groups.

Attitude Score: A substantial breach of the equal variances assumption is found using Levene's test for Attitude scores, with p-values for equal variances assumed and not assumed being 0.000 and 0.223, respectively. Even yet, the t-test with unequal variances

assumption produces a non-significant p-value of 0.223, meaning that, when all other factors are held constant, there is no discernible difference in the mean Attitude scores between the two groups.

Table-3: Attitude and Awareness result based on teaching experience

	Variable	N	Mean	S.D.	Levene's Test		t-test for Equality of Means		
					F	Sig.	t	Sig.	Result
Awareness score	< 10 Yrs	73	35.23	15.265	3.449	0.066	-0.067	0.947	NS
	> 10 Yrs	49	35.41	13.331					
Attitude score	< 10 Yrs	73	93.93	40.660	0.509	0.477	0.485	0.629	NS
	> 10 Yrs	49	90.12	43.717					

Awareness Score: Levene's test for Awareness scores gives p-values of 0.066 and 0.947 for equal and unequal variance assumptions, respectively, both beyond the 0.05 significance threshold. This implies that both possibilities satisfy the premise of equal variances. The fulfilled assumption is supported by the t-test with unequal variances assumption, which confirms a non-significant p-value (0.947) showing no significant difference in mean Awareness scores between the two groups when equal variances are not expected.

Attitude Score: For equal and unequal variance assumptions, respectively, Levene's test for Attitude scores produces non-significant p-values of 0.477 and 0.629, both of which surpass 0.05. This implies that both possibilities satisfy the premise of equal variances. The t-test with unequal variances assumption confirms that there is no significant difference, as evidenced by the non-significant p-value (0.629).

Findings of the study

- The mean scores for the Awareness score do not significantly differ between the two groups (Al-Enezi, 2018). On the other hand, the assumption of equal variances is broken for the Attitude score, where the mean scores for the two gender groups diverge significantly (Dirin 2019).
- Whether or not the premise of equal variances is satisfied, there is no discernible difference in the mean scores for the Awareness and Attitude scores between the two groups of educational status. Furthermore, regardless of whether the premise of equal variances is satisfied or not, there is no discernible difference in the mean scores for the Awareness and Attitude scores between the two groups of years of experience.

Implication of the study

It is simpler to incorporate current technology into the teaching of mathematics when teachers have a positive attitude and are highly informed of how to integrate augmented reality into their lessons. They can also increase professionalism, improve student academic accomplishment, and employ modern technology more effectively. It has been demonstrated that using augmented reality (AR) into mathematics instruction improves student engagement and learning results. The depiction of 3D geometrical objects made possible by AR can help

students comprehend and remember mathematical ideas (Yingprayoon, 2015). Additionally, it promotes understanding, motivation, and a greater level of engagement with the material (Coimbra, 2015). Meaningful learning can result from the use of augmented reality (AR) in mathematics instruction, which can foster a more engaging and dynamic learning environment (Carvalho, 2014). Additionally, the use of AR technology in STEM-based mathematics education holds great promise (Kramarenko, 2019). AR can improve critical thinking skills, spatial reasoning, and problem-solving abilities (Anggraini, 2020). It can also enhance learning motivation and confidence (Young, 2016), and foster spatial ability in middle school students (Ozcakir, 2021). Furthermore, AR can provide a better understanding of geometrical structures and improve learning abilities in mathematics (Yingprayoon, 2015).

Recommendation of the study

Based on the findings of the study, it is recommended that a high level of Awareness and positive Attitude in integrating Augmented Reality in teaching Mathematics are necessary to implement in the Teacher Education Curriculum for B.Ed trainees. So that prospective teachers could learn Augmented Reality and its effectiveness for the enhancement not only in Mathematics but also in other subjects. Secondly, the Nodal agency in the Department of School Education SCERT and RMSA must impart In-service training programs to the Mathematics teachers. At all the levels of the School, a system should be created to implement Augmented Reality in teaching Mathematics with proper infrastructure. The students also encouraged that the teacher must emphasize the integration of Augmented Reality in teaching Mathematics with respect to Gender, Educational Qualification and Years of Experience.

Conclusion

However, it is essential to be aware of potential challenges and limitations when implementing AR in mathematics education. These may include the cost and availability of AR devices, the need for proper teacher training, and ensuring that AR applications align with curriculum objectives. In general, greater learning results, more student engagement, and better readiness for the digital age can result from awareness of and favourable attitudes toward augmented reality in mathematics education. By embracing AR technology responsibly and effectively, educators can create a more inclusive, interactive, and dynamic learning environment for students.

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