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PAPER

Teachers' Perspectives on the Development of Augmented Reality Application in Geometry Topic for Elementary School

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ABSTRACT

Augmented Reality (AR) is a new evolving technology that can enhance the learning experience by making learning more engaging, has a beneficial influence on teaching and learning, and assists in comprehension, specifically when it comes to abstract concepts. Teachers play a pivotal role in accelerating the widespread use of AR in education, making it crucial to get their thoughts and perspectives. Based on the perspectives of mathematics teachers, this research aims to determine the necessity for developing an augmented reality learning application in the geometry topic for elementary school students through a questionnaire that has been answered by 52 elementary mathematics teachers from Northern State Malaysia. The findings of this study were analyzed using descriptive analysis with a value of Cronbach alpha ($\alpha = 0.98$). The findings of the study indicate three main elements that need to be emphasized for the AR development process, namely learning strategy design, presentation design, and interactivity design. Based on the mean of the research conducted, the findings of the three elements indicate a significant necessity. The development of AR applications must incorporate these three elements in order to assist elementary school mathematics teachers in designing AR learning applications that maximize student achievement.

KEYWORDS

augmented reality, teachers' perspective, geometry topic, mathematics, elementary school

1 INTRODUCTION

Education is evolving at a rapid pace. Over the years, learning media have evolved with the integration of modern digital media. In line with the rapid pace of technological innovation, technology integration in the realm of education has been widely applied to classroom instruction. Furthermore, education in the fourth industrial revolution necessitates the development of more interactive teaching strategies by teachers. Developed countries such as the United Kingdom, Germany, France, and

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the United States continue to create interactive and engaging learning media [1], [2], promoting the transformation of education in Malaysia. The Malaysian Education Development Plan, announced in 2013, focuses on the seventh shift, "*using educational technology to improve the quality of learning in Malaysia*." Furthermore, the primary school mathematics education curriculum emphasizes '*Creativity and Innovation*' and '*Information and Communication Technology*' (ICT) to produce creative and critical students, fascinating teaching and learning (T&L), and promote students' comprehension [3]. Moreover, using technology in T&L may foster a positive, attractive learning environment, fostering high-level thinking skills and the mastery of basic digital skills in students beginning at the elementary level [4].

Modern technology developments are influencing mathematics education. Teachers must develop content, pedagogy, and teaching design integrated with technology to generate engaging teaching and learning in the classroom [5]. Furthermore, applications designed for touchscreen devices are ideal especially for the youth, since they are attractive, simple, and convenient to use [6]. Previous research had indicated that inadequate visualization abilities were the key factors impacting pupils' understanding of geometric concepts, particularly the basic concepts of three-dimensional shapes [7], [8]. The geometry challenge highlighted prompted educators to strengthen their T&L practices.

Lecturers and teachers have employed various technologies as supporting materials for classroom T&L activities in mathematics [9]. For instance, the use of Dynamic Geometry Environments such as Cabri, GeoGebra, and Sketchpad via computers and mobile devices can strengthen students' understanding of describing geometric shapes in two dimensions (2D) and three dimensions (3D) and overcome problems associated with the visualization of shapes [10]. Aside from that, several teachers used PowerPoint presentations as a teaching medium to teach geometry [11]. Unfortunately, the slides provided were not constructive [11]. As a result, one educational medium that can assist students in teaching and learning geometry is the use of AR technology.

Nevertheless, AR technology teaching materials are still relatively new in Malaysia [10]. Most research on AR technology focuses on technological rather than pedagogical aspects [12]. According to [13], most teachers utilize AR applications without taking pedagogical considerations into account while designing learning activities. However, the impact of AR in education is determined by the combination of technological affordances and pedagogical approaches [13].

Since teachers are the catalyst in the educational technology advancement, it is important to understand the teachers' views about integrating AR in education. Numerous studies have been conducted to investigate the effectiveness of AR applications as well as students' perspectives, experiences, and outcomes of utilizing AR in education. However, few studies have looked at teachers' perspectives in developing AR applications [14]. This is an important factor to be considered in order to maximize the capacity of this technology in education. Thus, this study is aimed to identify the need for developing an AR learning application in the geometry topic based on mathematics teachers' perspectives.

2 LITERATURE REVIEW

The following literature review will provide an overview and analysis of research related to definitions of AR, benefits, and issues in implementing AR in mathematics education.

2.1 Definitions of augmented reality

AR technology is an alternative to supplementary learning materials or teaching media which has become a recent trend in education and learning research [15]. Scholars have presented various views and definitions of the concept of AR.

According to [16], AR is a 3D technology that enhances users' sensory perception of the world by producing a contextual layer of information. In the meantime, [17] and [18] described AR as a technology that allows computer-generated virtual images to accurately place physical objects in real-time. Additionally, AR is described as a situation in which the context of the real world is augmented by information or virtual objects [19]. Furthermore, AR technology is defined as a technology that integrates multimedia components such as 3D animation, images, graphics, audio, and video via cameras using tablets, iPads, smartphones, laptops, and computers [20].

Another definition of AR focuses on three characteristics: a) a combination of virtual and real-world elements, (b) running in real-time interactively and (c) registered in 3D shape [21][22]. An application must fulfil these three requirements to be deemed an AR. Despite the varied definitions of AR technology, it can be inferred that it is a visual effect produced by electronic devices. The visual objects generated by the device are added to the real-world scene displayed on the device's screen. As a result, users will discover that virtual objects generated by AR technology exist in the real-world.

2.2 Benefits of using AR in mathematics education

In mathematics education, AR technology provides enormous potential and opportunity for students to study and interact with 3D models in the real world [23]. Previous studies advocated the benefits of AR in mathematics education. First, AR can assist students comprehend abstract concepts by making them more understandable, allowing students to better understand learning content, and improving learning [24][25]. Second, AR can capture students' attention and concentration on the teacher's lesson [26]. Furthermore, AR can also enhance students' motivation [27][28], and lastly, learning through AR technology can provide a fun learning environment and improve students' spatial visualization abilities [29].

The use of AR in mathematics education has risen, specifically in T&L geometry [30][31]. According to these studies, the usage of AR gains positive impact on students' learning performance and attitude toward mathematics, particularly in classes that emphasize solid geometry and abstract geometric concepts.

2.3 Issues of using AR in mathematics education

Despite the abundance of evidence on the benefits of AR, several issues and challenges in utilizing AR in education have also been highlighted. According to [32] and [10], technical problems in handling AR applications, the cost of materials in developing AR, and the lack of competence in handling AR are among the issues and challenges in employing AR technology. Another study by [33] and [34] found that students who use AR require more training time than those who do not.

Moreover, most teachers have no expertise with AR [35][36]. More precisely, they lack appropriate technological and pedagogical skills [37, 38], such as programming skills and knowledge of 3D design software [39], and practical experience of AR content development [25]. This is because AR technology is still relatively new and is seldom used in T&L. Consequently, the design and development of AR applications must be tailored to the cognitive diversity of students to reduce students' challenges and issues when utilizing AR technology.

3 METHODOLOGY

The research employs a quantitative survey design method through an online questionnaire to capture teachers' perspectives about the development of AR applications in geometry topic for elementary school, with the goal of recording teachers' perspectives on learning strategies, presentation, and interactivity design for integrating AR in education.

3.1 Population and sample group

Population: The population of this study were mathematics teachers from elementary school in northern state, Malaysia.

Samples: The samples of this study were 52 mathematics teachers from elementary school. The samples size was randomly selected from 43 primary schools in northern states, Malaysia, based on Krejcie and Morgan's (1970) table [40]. The primary school mathematics teachers were chosen since the AR applications would be developed for learning mathematics, notably, geometry. Moreover, mathematics teachers play a vital role in the development of AR applications based on expertise in teaching mathematics to satisfy the needs of students while adhering to the mathematics education curriculum.

3.2 Research instrument

This study used a questionnaire on teacher needs as the research instrument. The questionnaire was divided into four parts: i) Respondents' Background, (ii) Learning Strategy Design, (iii) Presentation Design, and (iv) Interactivity Design. This research instrument was adapted from previous studies by [41] and [42]. This questionnaire consists of 27 items, nine for each part, on a five-point Likert scale ranging from "*strongly disagree*" to "*strongly agree*". The items in the questionnaire instrument are summarized in Table 1.

Table 1. Questionnaire instrument

No	Item	Number of Items
1	Learning Strategies	9
2	Presentation	9
3	Interactivity	9
Total Number of Items		**27**

The questionnaire items were validated by six experts in the language and curriculum content of mathematics education and the field of instructional technology validated. The content validity for all items in the questionnaire is one. Next, the questionnaire was tested with 35 mathematics teachers with the same characteristics as the samples to validate its reliability using the Cronbach Alpha coefficient reliability test. As a result, the average reliability was .95, with the overall reliability ranging from .95 to .96. According to [43], a Cronbach's alpha score of 0.8 to 1.0 indicates an effective degree of reliability with high consistency that can be used in research.

3.3 Data analysis

The descriptive statistics used in this study are frequencies, means, percentages, and standard deviations. The Statistical Package for Social Science (SPSS 26.0) software was used to determine the distribution and dispersion of the collected data. Each item in the questionnaire was analyzed based on the mean agreement interpretation from [44], as shown in Table 2, respectively.

Table 2. Mean agreement interpretation

Mean Scale	Interpretation
1.00 – 2.33	Low
2.34 – 3.67	Average
3.68 – 5.00	High

4 RESULTS

The results are presented in four sections, (i) Respondents' Background Information, (ii) Learning Strategy Design, (iii) Presentation Design, and (iv) Interactivity Design.

4.1 Background information about the respondent

The survey involved 52 mathematics teachers, with 39 (75.00%) male and 13 (25.00%) female teachers. Regarding their experience in teaching mathematics, 10 respondents have one to five years of teaching experience, representing 19.23% of the total sample. Similarly, 11 teachers have six to 10 years and 16 to 20 years of experience, representing 21.15%. The highest proportion of respondents has 11 to 15 years of teaching experience, with 23.08% of the total sample.

The items also probed the number of respondents who use each type of device for teaching math and the number of respondents who use a combination of devices. Three respondents (5.77%) use only smartphones, and three (5.77%) use only laptops. Meanwhile, 32 respondents (61.53%) use both smartphones and laptops, and 13 respondents (25.00%) use smartphones and tablets or iPads. Lastly, only one respondent (1.92%) reported using all three devices for teaching math (smartphone, tablet or iPad, and laptop).

In terms of frequency in using devices for teaching mathematics, eight respondents (15.38%) use devices rarely, 21 respondents (40.38%) use devices sometimes, and 23 respondents (44.24%) use devices frequently. The findings show that a high proportion of the respondents use devices frequently for teaching mathematics, while a smaller proportion uses them rarely. Finally, regarding the previous use of AR in class, 10 respondents reported that they have previously used AR in the classroom, accounting for 19.23% of the total while 42 respondents reported that they have not used AR in the classroom, representing 80.77% of the total. The respondents' background information and teaching are presented in Table 3, respectively.

Table 3. Respondents' background information (n = 52)

General Information	Item	Frequency (n)	Percentage (%)
Gender	Male	39	75.00
	Female	13	25.00
Experience in teaching mathematics	1–5 years	10	19.23
	6–10 years	11	21.15
	11–15 years	12	23.08
	16–20 years	11	21.15
	More than 20 years	8	15.39
Type of devices had been used for teaching mathematics	Smartphone	3	5.77
	Laptop	3	5.77
	Smartphone and Laptop	32	61.53
	Smartphone and Tablet/iPad	13	25.00
	Smartphone, Tablet/iPad, and Laptop	1	1.92
Frequency of using the devices for teaching mathematics.	Rarely	8	15.38
	Sometimes	21	40.38
	Frequently	23	44.24
Previous use of AR in class	Yes	10	19.23
	No	42	80.77

4.2 Learning strategies design

All items received a high mean score, with an overall mean score of 4.26 and a standard deviation of .68. The highest mean score preferred by teachers in learning strategies design for AR application development was item 5, with M = 4.37 and S.D. = .69. It appeared that 25 (48.1%) teachers strongly agreed that AR applications should integrate learning activities to encourage students' engagement. Meanwhile, the lowest mean score was item 2, with M = 4.17 and S.D. = .68. It appeared that 16 (30.8%) teachers strongly agreed that AR applications should deliver learning based on the relevance of the topic. Table 4 illustrates the findings of teachers' opinions on developing AR applications towards learning strategies design.

Table 4. Findings of perspectives of teachers towards learning strategies

Item	Level of Response					n	M	S.D.	I
	1	2	3	4	5				
AR application should:									
1. provide timely learning.	0	0	4	29	19	52	4.29	.61	High
	(0.0)	(0.0)	(7.7)	(55.8)	(36.5)	(100.0)			
2. deliver learning based on the relevance of the topic.	0	0	6	30	16	52	4.19	.63	High
	(0.0)	(0.0)	(11.5)	(57.7)	(30.8)	(100.0)			
3. incorporate active learning activities.	0	0	5	26	21	52	4.31	.64	High
	(0.0)	(0.0)	(9.6)	(50.0)	(40.4)	(100.0)			
4. provide students with opportunities for self-learning.	0	0	5	28	19	52	4.27	.63	High
	(0.0)	(0.0)	(9.6)	(53.8)	(36.5)	(100.0)			
5. integrate learning activities to encourage students' engagement.	0	0	4	23	25	52	4.37	.69	High
	(0.0)	(0.0)	(7.7)	(44.2)	(48.1)	(100.0)			
6. provide tasks that students may complete to assist with their learning.	0	0	8	24	20	52	4.23	.70	High
	(0.0)	(0.0)	(15.4)	(46.2)	(38.5)	(100.0)			
7. provide exercises that help strengthen students' conceptual understanding.	0	0	6	25	21	52	4.29	.67	High
	(0.0)	(0.0)	(11.5)	(48.1)	(40.4)	(100.0)			
8. provide a scoreboard on the exercises for student reference.	0	0	5	29	18	52	4.25	.62	High
	(0.0)	(0.0)	(9.6)	(55.8)	(34.6)	(100.0)			
9. provide feedback on exercises.	0	0	7	25	20	52	4.25	.68	High
	(0.0)	(0.0)	(13.5)	(48.1)	(38.5)	(100.0)			
Overall							**4.27**	**.65**	**High**

Notes: n=Frequency, M=Mean, S.D.=Standard Deviation, I=Interpretation.

4.3 Presentation design

All items obtained a high mean score. The mean scores for all items were above 4.00, with an overall mean score of 4.34 and a standard deviation of .68. The highest mean score preferred by teachers in presentation design for AR application development item 5 was M = 4.40 and S.D. = .65. It appeared that half of the respondents (50.0%) teachers strongly agreed that AR applications should use simple and easy language. Nevertheless, the lowest mean score was recorded for both item 2 and 3, with M = 4.29 and S.D. = .72. It appeared that 23 (44.2%) and 22 (42.3%) teachers strongly agreed that AR applications should use appropriate colors and icons. Table 5 displays the findings of teachers' opinions on developing AR applications towards presentation design.

Table 5. Findings of teachers' perspectives towards presentation design

Item	Level of Response					n	M	S.D.	I
	1	2	3	4	5				
AR application should:									
1. use appropriate colours.	0	0	8	21	23	52	4.29	.72	High
	(0.0)	(0.0)	(15.4)	(40.4)	(44.2)	(100.0)			
2. use appropriate icons.	0	0	7	23	22	52	4.29	.72	High
	(0.0)	(0.0)	(13.5)	(44.2)	(42.3)	(100.0)			
3. have user-friendly navigation icons.	0	0	4	27	21	52	4.33	.62	High
	(0.0)	(0.0)	(7.7)	(50.0)	(40.4)	(100.0)			
4. contain interactive buttons that are easy to understand.	0	0	5	28	19	52	4.37	.69	High
	(0.0)	(0.0)	(9.6)	(53.8)	(36.5)	(100.0)			
5. use simple and easy language.	0	0	5	21	26	52	4.40	.65	High
	(0.0)	(0.0)	(9.6)	(40.4)	(50.0)	(100.0)			
6. in line with the mathematics curriculum content.	0	0	6	21	25	52	4.37	.69	High
	(0.0)	(0.0)	(11.5)	(40.4)	(48.1)	(100.0)			
7. provide an easy-to-use main menu system.	0	0	5	26	21	52	4.31	.64	High
	(0.0)	(0.0)	(9.6)	(50.0)	(40.4)	(100.0)			
8. provide user manuals that are easy to understand.	0	0	4	23	25	52	4.37	.69	High
	(0.0)	(0.0)	(7.7)	(44.2)	(48.1)	(100.0)			
9. able to transition smoothly forward or backward without following a sequential order.	0	0	7	21	24	52	4.33	.71	High
	(0.0)	(0.0)	(13.5)	(40.4)	(46.1)	(100.0)			
Overall							**4.34**	**.68**	**High**

Notes: n=Frequency, M=Mean, S.D.=Standard Deviation, I=Interpretation.

4.4 Interactivity design

The mean scores for all items exceed 4.00, with an overall mean score of 4.34 and a standard deviation of .63. The overall mean score suggests a high level of agreement. Specifically, the highest mean scores were item 3 and item 9, with M = 4.40 and S.D. = .63. It appeared that 25 (48.1%) teachers strongly agreed that AR applications should provide available and well-organized links as well as activities that encourage students' ability to visualize shapes. Next, the lowest mean score was obtained from item 1, with M = 4.21 and S.D. = .83. It appeared that 21 (40.4%) teachers strongly agreed that AR applications should allow students to repeat the exercise. Table 6 illustrates the findings of teachers' opinions on developing AR applications towards interactivity design, respectively.

Table 6. Findings of perspectives of teachers towards interactivity

Item	Level of Response					n	M	S.D.	I
	1	2	3	4	5				
AR application should:									
1. allow students to repeat the exercise.	0	0	8	23	21	52	4.25	.71	High
	(0.0)	(0.0)	(15.4)	(44.2)	(40.4)	(100.0)			
2. provide students with easy access to instructional resources.	0	0	6	23	23	52	4.33	.68	High
	(0.0)	(0.0)	(11.5)	(44.2)	(44.2)	(100.0)			
3. provide available and well-organized link.	0	0	4	23	25	52	4.40	.63	High
	(0.0)	(0.0)	(7.7)	(44.2)	(48.1)	(100.0)			
4. provide systematic structure to facilitate exploration.	0	0	5	25	22	52	4.33	.65	High
	(0.0)	(0.0)	(9.6)	(48.1)	(42.3)	(100.0)			
5. provide students with task to aid them learning.	0	0	5	24	23	52	4.35	.65	High
	(0.0)	(0.0)	(9.6)	(46.2)	(44.2)	(100.0)			
6. create tasks to help students understand geometry concepts.	0	0	3	26	23	52	4.38	.60	High
	(0.0)	(0.0)	(11.5)	(50.0)	(44.2)	(100.0)			
7. provide activities for problem solving.	0	0	6	26	20	52	4.27	.66	High
	(0.0)	(0.0)	(11.5)	(50.0)	(38.5)	(100.0)			
8. Allow for the rotation of 3D shape images at different angles.	0	0	5	26	21	52	4.31	.64	High
	(0.0)	(0.0)	(9.6)	(50.0)	(40.4)	(100.0)			
9. Provide activities that encourage students' ability to visualize shapes.	0	0	4	23	25	52	4.40	.63	High
	(0.0)	(0.0)	(7.7)	(44.2)	(48.1)	(100.0)			
Overall							**4.34**	**.65**	**High**

Notes: n=Frequency, M=Mean, S.D.=Standard Deviation, I=Interpretation.

5 DISCUSSION

The three aspects were discussed in the following subsections.

5.1 Learning strategies design

The total mean score item for learning strategy design demonstrates a high level of agreement among the mathematics teachers. According to the features of AR development related to the learning strategies, the incorporation of learning activities to enhance students' participation is indeed a significant focus. Teachers may foster student engagement and involvement in the T&L process by providing activities that include active participation, such as solving AR-based math problems and exploring virtual simulations of shapes.

The emphasis on increasing students' participation aligns with the principles of constructivist learning theories [45], which promote hands-on experiences and student-centered approaches. AR technology provides a dynamic and interactive learning environment that can facilitate active learning, critical thinking, and problem-solving skills. On the other hand, the findings were also suggesting that AR applications should provide timely, relevant, opportunities for self-learning, provide exercises or tasks that strengthen students' conceptual understanding and offer feedback and scores for reference. All these features enabled students to learn geometry independently according to the compatibility of the student's learning environment. Therefore, the feedback from the respondents indicates that AR applications loaded with these features could be developed as a useful tool for facilitating learning in the context of learning strategies design.

5.2 Presentation design

Overall, the mean score for presentation design shows a high level of concern among mathematics teachers. The usage of simple and easy language is a significant priority in AR development characteristics connected to presentation design. In the context of AR development, the use of simple and easy language can enhance the effectiveness of AR presentations and interactions. It is important to take into account the intended audience while designing AR applications, which often includes learners with varying levels of prior knowledge and language proficiency. Teachers can ensure that instructional content is easily understandable and engaging for all students by using clear, concise, and accessible language. Besides, the features and characteristics of AR technology should provide the learner with clear and concise information [46][47].

Furthermore, the findings on presentation design for AR applications were also suggesting using appropriate colors, icons, and navigation buttons for designing an effective and user-friendly interface AR applications. According to [48], designers should also consider the notion that AR applications should be developed in line with the content of the mathematics curriculum. This implies that the application's content should be aligned with educational standards. In addition, providing an easy-to-use main menu system, user manuals that are easy to understand, and allowing smooth transitions forward or backwards without following a sequential order are also considered important design features.

5.3 Interactivity design

The overall mean score for interactivity design illustrates a high level of agreement across mathematics teachers, making interactivity a crucial aspect of AR applications. Activities that promote students' capacity to visualize shapes and give accessible and well-organized links were a prominent consideration of AR development features related to interactivity design. Interactivity aspects are essential for completing the interactive communication process, as is how much teachers expect or engages with their students when teaching using multimedia [49].

These findings also suggest that AR applications should be designed to focus on interactivity to provide an engaging and effective learning experience for students.

This is congruent with [48] and [50], where technological advances such as AR enable high engagement and immersion, which can boost learning outcomes, particularly in STEM education. Next, by allowing students to repeat exercises, AR applications can facilitate learning and help students achieve better learning outcomes. Additionally, providing a systematic structure, activities, and tasks to assist students in understanding concepts can ensure that they can apply what they have learned in real-world situations.

However, there are several challenges that lie within this questionnaire from the teachers' perspectives or views. Since the entire process is conducted online, it creates barriers to communication with the teachers. Moreover, a majority of teachers in this study do not employ AR in their T&L, according to the respondents' backgrounds. There might be some factors and obstacles limiting them from utilizing AR in class. Thus, future studies on the benefits, disadvantages, and challenges of using AR applications in education should be considered, as this research does not concentrate on the issues and barriers that teachers face when implementing AR in mathematics education.

6 CONCLUSION

This study was conducted to determine the necessity of developing AR applications for teaching geometry topics from the perspectives and views of mathematics teachers to fulfil the needs of primary school students. It is generally accepted that AR has the potential to assist T&L. In order to successfully use AR in mathematics education, it is vital to take into account the opinions and perspectives of the teachers. The perspectives and ideas of teachers about the use of AR in educational practice are of utmost significance due to the fact that they are often the primary advocates of any technology implemented in educational settings.

This study conducted a survey among mathematics teachers more specific to T&L of geometry. According to these teachers' views, three main elements need to be emphasized for the AR development process, namely learning strategy design, presentation design, and interactivity design. Based on the mean of the research conducted, the findings of the three elements indicate a significant necessity.

As the exploration of the usage of AR technology in elementary schools was in its initial stages, this study focused on developing an AR application. While most students currently utilize smartphones, the idea of developing AR applications corresponds to the students' demands. It was intended that this study will aid teachers in developing AR applications based on teacher-perceived characteristics. Concurrently, it will assist teachers and the researchers in introducing new learning strategies using AR technology to produce more creative and inventive T&L.

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