

USING AUGMENTED REALITY FOR GEOMETRY LEARNING: INDONESIAN ELEMENTARY SCHOOL TEACHERS' EXPERIENCES

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ARTICLE INFO	ABSTRACT
<p>Article History: Received 03/01/2023 Revised 22/03/2023 Approved 29/03/2023 Published 16/05/2023</p> <hr/> <p>Keywords: Augmented reality Mathematics Geometry Elementary school teachers Instructional media</p>	<p>This study aims to discover Indonesian elementary school teachers' experiences (n = 257) of using Augmented Reality (AR) for learning, especially related to one of the topics in mathematics learning, namely, geometry. AR is considered to be an alternative instructional media that can be utilized for teaching geometry, including the topic of three-dimensional shapes. A questionnaire consisting of both close-ended and open-ended questions was used to collect data in this study. This study has successfully revealed teachers' use of digital instructional media during the COVID-19 pandemic, their familiarity with AR, frequency of AR use for geometry learning, and challenges in using it.</p>
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INTRODUCTION

Augmented reality (AR) is one of the emerging technologies used in education. AR is a technology that can overlay a virtual (computer-generated) object into the real world (Akçayır & Akçayır, 2017). Moreover, Azuma et al. (2001) state that AR technology has several properties, namely “combines real and virtual objects in a real environment; runs interactively, and in real time; and registers (aligns) real and virtual objects with each other”. Its extensive use in education is because AR no longer requires costly hardware such as head-mounted displays (HMD), instead, educators can harness this technology by using mobile devices (Akçayır & Akçayır, 2017). As a result, many studies have been conducted concerning the use of AR in various levels of education, including early childhood education, primary education, secondary education, and higher education (Garzón et al., 2019). Moreover, the systematic review and meta-analysis study by Garzón et al. (2019) also found that almost 50% of the studies investigated the use of AR in the broad field of natural sciences, mathematics, and statistics. It is probably because AR is beneficial for teaching abstract concepts (Garzón et al., 2019).

The use of AR in mathematics learning has various purposes, one of which is related to geometry learning (Ahmad & Junaini, 2020). For instance, Andrea et al. (2019) developed an AR-based application called “Magic Boosed” to increase elementary students' interest in and understanding of 3D geometry. Similarly, a study conducted by Demitriadou et al. (2020) found that AR enhanced interactivity and students' interest in learning geometric solids, resulting in better learning efficiency and understanding than conventional teaching methods. In short, studies have shown that AR has various positive impacts on mathematics learning in elementary education, including geometry lessons.



Table 1. Demographic profile of participants.

Demographic Profile		f	%
Gender	Male	75	29.18
	Female	182	70.82
Age	21–30	97	37.74
	31–40	119	46.30
	41–50	25	9.73
	51–60	16	6.23
Educational degree	Diploma	1	0.39
	Bachelor	239	93.00
	Master	16	6.23
	Doctorate	1	0.39
School type	Public	248	96.50
	Private	9	3.50

Since AR can be utilized to enhance mathematics learning quality, particularly geometry learning, it can be argued that teachers should be encouraged to implement AR in their classrooms. However, integrating new technology into a classroom requires careful consideration and preparation, including aspects related to teachers. It is because adopting new technology depends on teachers' perceptions and perspectives (Jamrus & Razali, 2021) and their willingness and skills (Ashley-Welbeck & Vlachopoulos, 2020). Thus, it is crucial to investigate teachers' current state of knowledge and experiences of using AR in learning to utilize this technology effectively.

Many studies have been performed to understand teachers' perspectives or experiences related to the use of AR for learning, such as in preschool science education (Ozdamli & Karagozlu, 2018), primary science education (Alalwan et al., 2020), primary education in general (Alkhatabi, 2017), English reading in secondary education (Jamrus & Razali, 2021), and within various subjects in secondary education (Tzima et al., 2019). However, there are limited to no studies investigating elementary school teachers' perspectives or experiences related to AR after they experienced the COVID-19 pandemic. The COVID-19 pandemic has significantly changed how education is delivered as it relies more on digital technology than ever. Moreover, there are also various challenges in using AR in e-learning contexts (Alzahrani, 2020). Therefore, this study aims to investigate elementary school teachers' use of digital instructional media during the COVID-19 pandemic, their familiarity with AR technology, their experience of using it, and the challenges they faced in using it in the Indonesian context. It is crucial to investigate this issue to determine their readiness to use AR in their classrooms.

METHOD

A survey was conducted from 19–26 April 2022 to investigate the issue in the present study. The survey method was used as this method is useful for “describing the nature of existing conditions” (Cohen et al., 2018). The type of survey used in this study was a cross-sectional survey design as it can “examine current attitudes, beliefs, opinions, or practices” (Creswell, 2014). The data collection process was done by using a questionnaire consisting of questions related to (1) the frequency of digital instructional media use during the COVID-19 pandemic; (2) types of digital instructional media used in mathematics learning in general (any topic) and specifically on geometry topics during the COVID-19 pandemic; (3) teachers' familiarity with AR; (4) frequency of AR use for geometry learning before and during the COVID-19 pandemic; and (5) challenges in using AR for learning.

The questionnaire was created using google forms which then was shared through WhatsApp messaging application. The use of internet survey in this study was because it (1) requires lower cost; (2) takes less time; (3) reaches a broader audience; (4) collects a much larger number of data; (5) is more convenient for respondents; and (6) yield higher response rates (Cohen et al., 2018). This process resulted in 257 elementary school teachers from 39 cities in Indonesia participating in this study. The demographic profile of the participants is presented in Table 1.

The quantitative and qualitative data obtained through the questionnaire were then analyzed descriptively. Since the participants came from many cities in Indonesia, it is expected that the findings of this survey can provide representative information regarding teachers' experiences related to the use of digital instructional media, especially AR, for mathematics learning, including geometry. Therefore, necessary actions and policies can be taken to promote AR in elementary education in Indonesia.

RESULTS

Digital Instructional Media Use During the COVID-19 Pandemic

Before focusing specifically on elementary school teachers' experience of using AR for learning, this study first inquired about the use of digital instructional media during the COVID-19 pandemic. Table 2 shows the frequency of digital instructional media use during the COVID-19 pandemic. In terms of their use in various subjects, the highest number of responses was in the “often” category (44.75%) followed by the “sometimes” category “42%.80” indicating a sufficient use of digital instructional media when it comes to various subjects taught in elementary classrooms. However, concerning their use in mathematics learning in general (any topic), the

Table 2. Frequency of digital instructional media use during the COVID-19 pandemic (n = 257).

Statement	Always		Often		Sometimes		Rarely		Never	
	f	%	f	%	f	%	f	%	f	%
I used digital instructional media (any subject) during the COVID-19 pandemic	22	8.56	115	44.75	110	42.80	7	2.72	3	1.17
I used digital instructional media for mathematics learning (any topic) during the COVID-19 pandemic	12	4.67	80	31.13	132	51.36	25	9.73	8	3.11
I used digital instructional media for mathematics learning (geometry topic) during the COVID-19 pandemic	10	3.89	66	25.68	131	50.97	37	14.40	13	5.06

Table 3. Types of digital instructional media used in mathematics learning during the covid-19 pandemic.

Type of Digital Instructional Media	Any Topic		Geometry Topics	
	f	%	f	%
Text (e.g., e-books, e-worksheets, webpages)	135	20.03	126	21.00
Audio (e.g., podcasts, digital music, digital sound recordings)	84	12.46	56	9.33
Visual (e.g., digital pictures, digital photos, and digital diagrams)	189	28.04	183	30.50
Video (e.g., documentary films, video recordings of a particular event, streamed videos)	167	24.78	157	26.17
Manipulative (digital interactive maps, tangrams, digital games)	41	6.08	41	6.83
People (teachers, figures, and professionals who present in virtual meetings)	58	8.61	37	6.17
Other media	0	0.00	0	0.00
Total	674	100.00	600	100.00

highest percentage of responses was in the “sometimes” category with 51.36%, followed by the “often” category with “31.13% category” indicating a need to encourage teachers to use digital media for mathematics learning. Similarly, with regard to their use in geometry learning, the category with the highest percentage of responses was the “sometimes” category, with 50.97%. Moreover, only 25.68% of the teachers stated that they often used digital instructional media during the COVID-19 pandemic. Furthermore, almost 15% of the teachers stated that they rarely used this type of media, indicating a need to promote various digital instructional media for geometry learning.

The second inquiry was related to types of digital instructional media used in mathematics subject during the COVID-19 pandemic. Table 3 presents the results of one of the questions in the questionnaire investigating different types of digital instructional media that teachers might use, namely, text, audio, visual, video, manipulative, and people. Table 3 shows that the highest percentage of responses for mathematics topics in general and specifically for geometry topics was on visual instructional media, with 28.04% and 30.50%, respectively. It can be argued that visual is the most needed type of media for mathematics learning in general and for geometry learning.

Teachers' Experience of Using AR

The third inquiry was related to teachers' familiarity with AR. The inquiry was crucial to determine whether teachers were familiar with or possessed the necessary knowledge related to AR use for learning. Figure 1 shows that out of 257 teachers who participated in this study, only around 28% of them stated that they were familiar with AR technology. Whereas most of the respondents (around 72%) stated that they were unfamiliar with this technology. This finding indicates the need to introduce AR technology and AR-based instructional media to elementary school teachers.

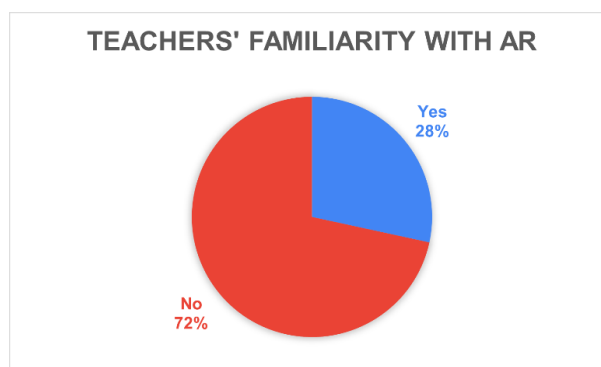
**Figure 1.** Teachers' familiarity with AR (n = 257).

Table 4. Teachers' familiarity with AR by age groups (n = 257).

Age Group	Yes		No	
	f	%	f	%
21–30	32	32.99	65	67.01
31–40	30	25.21	89	74.79
41–50	6	24.00	19	76.00
51–60	5	31.25	11	68.75
All Age Groups	73	28.40	184	71.60

Table 5. Frequency of AR use for geometry learning before and during the COVID-19 pandemic (n = 73).

Statement	Always		Often		Sometimes		Rarely		Never		Not Answered	
	f	%	f	%	f	%	f	%	f	%	f	%
I used AR-based instructional media for geometry learning before the COVID-19 pandemic	5	6.85	3	4.11	10	13.70	16	21.92	37	50.68	2	2.74
I used AR-based instructional media for geometry learning during the COVID-19 pandemic	5	6.85	3	4.11	9	12.33	19	26.03	34	46.58	3	4.11

Table 6. Challenges in using AR for learning.

Type of challenge	f	%
Limited devices (e.g. smartphones) available	46	31.51
Technical problems (e.g. slow internet connection)	39	26.71
Lack of knowledge and skills among teachers about using AR in education	28	19.18
Technology is considered complex, so it is sometimes difficult to use	20	13.70
Add cognitive load for students	7	4.79
No challenges	4	2.74
Other challenges	2	1.37
Total	146	100.00

In addition, [Table 4](#) demonstrates the teachers' familiarity with AR by age group. [Table 4](#) shows that in every age group, the number of teachers who were familiar with AR was always lower than the number of those who were not familiar with this technology. This finding denotes that most elementary school teachers in Indonesia, regardless of age, still need to be introduced to this type of technology. The 73 respondents who stated that they were familiar with AR technology were then asked to respond to questions related to the fourth inquiry, namely, the frequency of AR use for geometry learning before and during the COVID-19 pandemic. [Table 5](#) shows that although they were familiar with AR technology, most respondents either never (50.68%) or rarely (21.92%) used AR for geometry learning before the pandemic. Similarly, concerning its use during the COVID-19 pandemic, 46.58% of the teachers stated that they never used it, and 26.03% of them rarely used it. In total, both before and during the COVID-19 pandemic, around 73% of them either never or rarely used AR-based instructional media for geometry learning.

Furthermore, teachers were also asked to mention AR applications they used in learning (any subject). Some of the AR applications they mentioned were Animal 4D, AR-Rumah Belajar, DEVAR - Augmented Reality App, Google Sky Map, and Quiver 3D Coloring App. The teachers who stated that they were familiar with AR (n = 73) were also asked about challenges in using AR. In the questionnaire, they were provided with several challenges and allowed to choose more than one challenge. The teachers' responses to this fifth inquiry are presented in [Table 6](#), sorted from the most frequent to the least frequent challenges.

[Table 6](#) shows that two of the most common challenges in using AR for learning were related to information and communication technology (ICT) infrastructure, namely, limited device availability (31.51%) and technical problems (26.71%). Whereas the next two other problems were related to users' competencies, namely, teachers' lack of knowledge and skills related to using AR in education (19.18%) and their views that perceived AR technology as difficult to use (13.70%). These findings show that preparing both ICT infrastructure and teachers' digital competencies is critical to ensure the success of AR use in education.

DISCUSSION

The first two inquiries, which were related to the use of digital instructional media during the COVID-19 pandemic, resulted in two main findings. Firstly, the highest number of responses to the question related to the frequency of digital instructional media use during the COVID-19 pandemic was in the "sometimes" category. Secondly, in terms of the type of digital instructional media used for mathematics learning (both any topic and specifically geometry topic) during the COVID-19 pandemic, it was the visual type of media that received the highest percentages. Based on these two findings, it is deemed appropriate and crucial to encourage elementary school teachers to use AR as a type of digital instructional media that can be used for enhancing visualization ([Ahmad & Junaini, 2020](#);

Herrera et al., 2019). Moreover, AR will also be beneficial for various topics in mathematics in elementary school as it can facilitate students in learning abstract concepts (Garzón et al., 2019; Ibáñez et al., 2014).

The third inquiry, which was related to elementary school teachers' familiarity with AR, revealed that only around 28% of them were familiar with AR. Moreover, when the teachers were grouped into several age groups, it was found that in every group, the percentage of teachers familiar with AR technology was always lower than the percentage of those unfamiliar with it. This finding is different from the study conducted by Alkhatabi (2017), which found that 71.3% of female and 83.5% of male primary school teachers in Saudi Arabia were familiar with AR. Therefore, it is crucial to take the necessary actions to introduce AR to elementary school teachers in Indonesia.

The fourth inquiry was about the frequency of AR use for geometry learning before and during the COVID-19 pandemic. The data showed that among the participants who stated that they were familiar with AR technology, the majority (73%) either never or rarely used this technology for geometry learning before and during the COVID-19 pandemic. Thus it is important to investigate why they did not use AR for geometry learning before and during the COVID-19 pandemic. It is especially considering the fact that various studies have shown that AR can be beneficial for geometry learning, including increasing understanding of geometrical shapes (Gecu-Parmaksiz & Delialioğlu, 2019), increasing understanding of 3D geometry and shape (Andrea et al., 2019), enhancing visualization (Ahmad & Junaini, 2020; Herrera et al., 2019), and increasing interactivity and students' interest in learning geometric solids (Demitriadou et al., 2020).

The fifth inquiry focused on challenges in using AR for learning. The data showed that two challenges related to the lack of ICT infrastructure were the most common challenges in using AR for learning. In addition, the two other common challenges were related to users' digital competencies. This finding is consistent with the previous study conducted by Alkhatabi (2017), which found that three main obstacles facing elementary school teachers in using AR in Saudi schools were lack of information technology (IT) skills, lack of sufficient ICT infrastructure, and resistance to change. Therefore, besides improving the ICT infrastructure, it is also essential to improve Indonesian elementary school teachers' digital skills. Literature has shown that teachers have been ill-prepared when it comes to utilizing technology for teaching (Foulger et al., 2017). Therefore, it is essential to improve the quality of teacher education so that teacher candidates will be equipped with adequate digital competencies and willing to keep up to date with the recent advancements in technology.

CONCLUSION

This study investigates Indonesian elementary school teachers' experiences ($n = 257$) of using AR for learning, especially related to geometry learning. Several key takeaways of this study are (1) it is considered appropriate and crucial to encourage elementary school teachers to use AR as a type of digital instructional media that can be used for enhancing visualization and facilitating students in learning abstract concepts; (2) it is crucial to take necessary actions to introduce AR to elementary school teachers in Indonesia; (3) it is important to investigate the reasons why they did not use AR for geometry learning before and during the COVID-19 pandemic; and (4) it is essential to improve the quality of teacher education so that teacher candidates will be equipped with adequate digital competencies and also be willing to keep up to date with the recent advancements of technology. Despite successfully revealing information regarding the Indonesian elementary school teachers' use of digital instructional media during the COVID-19 pandemic, their familiarity with AR, frequency of AR use for geometry learning, and challenges in using it, this study is not without limitations. One of the limitations of this study is that most of the respondents were teachers working in public schools (96.50%). The results might be different when there is a higher percentage of teachers from private schools as they usually have sufficient ICT infrastructure. In addition, the data collection technique used in this study was only a questionnaire. The future study might employ different techniques, such as interviews, to gain deeper insight into this issue.

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AUTHOR CONTRIBUTIONS

All authors contributed to the conception and design of the study, data collection, analyze, interpretation, writing, and revision of the manuscript. All authors approved the final version of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interests with respect to the research, authorship, and publication of this article.

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