Malaysian Journal of Mathematical Sciences 18(1): 51–72 (2024)
https://doi.org/10.47836/mjms.18.1.04

Malaysian Journal of Mathematical Sciences
Journal homepage: https://mjms.upm.edu.my

Implications of AR Modules on Geometry Conceptual and Procedural Knowledge among Primary School Students

Nadzri, A. Y. N. M.[1], Ayub, A. F. M.*[1,2], Zulkifli, N. N.[3], and Salim, N. R.[2]

[1] *Faculty of Educational Studies, Universiti Putra Malaysia,*
43400 UPM Serdang, Selangor, Malaysia
[2] *Institute for Mathematical Research, Universiti Putra Malaysia,*
43400 UPM Serdang, Selangor, Malaysia
[3] *Faculty of Humanities, Management and Science, Universiti Putra Malaysia,*
UPM Bintulu, Malaysia

E-mail: afmy@upm.edu.my
**Corresponding author*

Received: 14 August 2023
Accepted: 5 December 2023

Abstract

Looking at the weakness of students in learning geometry, a study was conducted on using modules with augmented reality technology for primary school students. This study aims to identify the effectiveness of using such modules on students' conceptual and procedural knowledge in geometry, particularly for Year 4. A random sampling of students was conducted to determine the experimental group of students who studied using modules with augmented reality. In contrast, the control group studied with traditional module methods. Fifty-nine students were involved in this study, with 29 in the experimental group and 30 in the control group. The study results analyzed by ANCOVA showed that the conceptual and procedural scores of the experimental group students were significantly better than the control group students in the post-test and the delayed post-test. Using modules with augmented reality benefits students' conceptual and procedural knowledge in learning geometry. This study indirectly allows students to learn geometry concepts through an augmented reality technology approach with smart devices. Students also have the opportunity to learn through a student-centered approach and collaborative learning strategies while using augmented reality applications in learning. Simultaneously, using this technology is an innovation that also benefits teachers and stakeholders.

Keywords: augmented reality; conceptual knowledge; geometry, module, procedural knowledge; Spatial.

1 Introduction

Augmented reality can potentially be used in teaching complex concepts such as Science, History, Arts, and more [4]. Various disciplines, such as mathematics, can apply augmented reality to enhance learning [26]. Studies on augmented reality were conducted to convey abstract concepts such as geometry [3] and Coordinates [19, 37]. Students can explore shapes from different dimensions and see the angles, sides, and features of a shape through the effects offered in an augmented reality application. According to Pedaste et al. [35], the performance of students who are taught with the aid of augmented reality applications is better than the use of the web, which is static and does not offer direct interaction with materials.

Students experience problems in geometry when they struggle to visualise shapes, especially three-dimensional shapes. Challenges are encountered when students are given stimulus materials such as two-dimensional figures. This challenge is stated in the study of Abdinejad et al.[1], which states that the biggest difficulty for students is to imagine the model or shape of a three-dimensional structure in a two-dimensional version. Students cannot recognise and describe three-dimensional features that are not visible in the two-dimensional diagram, which in turn leads to misconceptions about shapes and leads to errors when solving problems involving geometry [20]. This problem occurs following students' weakness in visualising shapes, which is an important support in learning geometry concepts [44]. Conceptual knowledge needs to be solid to enable students' mastery of procedural knowledge in geometry. Thus, the solution proposed to overcome the weakness of students' visualisation in three-dimensional space is through the use of augmented reality applications such as the independent study by Krüger et al. [24].

Studies in the medical field recognize that introducing abstract concepts is appropriate using augmented reality application technologies [8, 12]. Meanwhile, teaching abstract concepts in education requires students to have cognitive thinking equivalent to how the teacher delivers learning [28]. Geometry learning is one of the abstract topics that students need to learn starting from primary school [25, 30]. The abstract concept of geometry is shown through the visualization of three-dimensional shapes on a two-dimensional diagram on a chalkboard or textbook [18]. Geometry is a subject that needs to be explored to improve conceptual understanding, memorize formulas, and recognize axioms and related theories. This understanding can be enhanced by stimulating augmented reality technology that offers simulation and exploration activities during its use [35]. This technology can also depict more complex geometric shapes without needing actual manipulative materials that cost more [18].

Traditionally, teaching and learning of geometry have focused more on the recognition of two-dimensional and three-dimensional features, area, and volume, thus limiting students' ability to develop and nurture spatial thinking and visualization, which can be enhanced through interaction with the technological environment [11, 15]. Indirectly, the use of augmented reality can incorporate the skills of using technology in mathematics as outlined in the DSKP curriculum [25]. Related studies of augmented reality use quantitative approaches with experimental designs such as [3, 16, 40], model adaptation [9, 22, 33] and exploratory studies [2, 15, 36]. Concerning that, this current study aims to identify the implications of using modules with augmented reality integration on the conceptual and procedural knowledge of year 4 students in primary schools.

Conceptual knowledge is fundamental to the reinforcement of a particular concept. Good conceptual knowledge is essential in mastering procedural knowledge of a topic. According to Mohamed Elsayed [13], in his study of mathematics learning, conceptual knowledge refers to a deep understanding of the function of mathematics in terms of ideas, terms, concepts, generalizations, and relationships that promote the connection between existing knowledge and new knowledge.

Procedural knowledge refers to the step-by-step translation of conceptual understanding in the form of algorithms that are structured in practice to show how to solve mathematical problems. For Stovner and Klette [41], procedural knowledge is a skill about procedures that helps students get the correct answer by using formulas and facts directed to the solution.

Conceptual and procedural knowledge in mathematics is usually used as a variable and studied simultaneously in several independent studies. One of the related studies states that learning mathematics through the STEM (Science, Technology, Engineering, Mathematics) approach shows effectiveness in terms of mastery of mathematics in examinations developed to test students' conceptual and procedural knowledge in addition to several other aspects tested [13]. The quasi-experimental study showed positive results on experimental groups' conceptual and procedural knowledge using the STEM approach compared to control groups using traditional methods. The results showed significant differences in post-test scores analyzed through the T-test.

In addition, a qualitative study also addressed the study of conceptual and procedural knowledge in the subject of mathematics for prospective teachers. The study by Klau et al. [23] states that conceptual understanding concerns the ability of individuals to say why a formula is used or the ability to interpret equations based on thinking rather than simply answering. Therefore, this study was conducted with interviews to analyze how prospective teachers answer questions conceptually regarding linear algebra. The study also seeks to identify prospective teachers' procedural knowledge level through interviews to interpret how they choose steps and procedures to answer given questions. The study's significance was intended to determine the extent of thinking and the purpose of prospective teachers' conceptual and procedural knowledge in solving problems related to linear algebra. The study showed that specific problem-solving procedures still bind students who do not understand how to solve routine problems and use wrong concepts in solving mathematics problems [23]. However, this study focused on primary school students to fill the gap in studies that were conducted previously.

A quasi-experimental study was conducted with 30 samples for each group to improve the quality of attitudes, conceptual knowledge, and procedural skills in teaching differential calculus. The study formulated that using a technology known as Microsoft Mathematics can improve students' conceptual understanding and procedural skills [31, 38]. At the same time, it can increase the quality of attitudes of students taught with technology towards experimental groups. Other studies using technology in calculus also show a similar impact. According to Bedada and Machaba [5], the use of Geogebra software in helping students learn calculus through a cycle model positively affected the conceptual knowledge and procedural understanding of students at a university in Ethiopia. The use of Geogebra technology allowed students to do self-exploration visually and, at the same time, promote a social learning environment.

A previous study on Year 4 students' conceptual and procedural knowledge in solving mathematical problems was conducted in a quasi-experimental setting in Malaysia. The topic focuses on problem-solving in fractions. The results of the ANCOVA analysis showed that students who used the problem-solving module were significantly better in conceptual and procedural knowledge scores than students who used conventional methods [32]. Similar to problem-solving modules, the study by Hakim et al. [17] also proved that experimental group students using modules with augmented reality improved problem-solving skills compared to the control group. This skill is built when students' conceptual and procedural knowledge has been strengthened through the intervention. Meanwhile, studies that address students' conceptions and learning approaches to self-efficacy levels show that augmented reality can help students with high self-efficacy apply more contextualized strategies in learning mathematics [7].

A study to identify the effect of the RMT (Rigorous Mathematical Thinking) strategy on students' conceptual knowledge and strategy competence was conducted involving 7th-grade secondary students in Ngawi, Indonesia, which showed that students in the experimental group with the RMT approach showed significantly better conceptual knowledge compared to the control group taught conventionally [34]. The study findings were obtained through MANOVA analysis and the independent sample T-test. The discussion of the study by Samphantakul and Thinwiangthong [39] also stated that good conceptual knowledge was shown after using the technology intervention, namely GSP. The study recommends that technology be applied in future studies so students can solve mathematics problems independently.

Meanwhile, in a study by Yurniwati and Soleh [43] discussing conceptual and procedural knowledge, it is stated that the implementation of geometry teaching by primary school teachers makes students unable to master the more profound fundamental concepts of geometry. The study recommends that emphasis be given to teaching aids in developing conceptual knowledge, especially in geometry. Another study also showed the findings of the mastery of conceptual knowledge of geometry of prospective teachers to be still weak and needed to be developed according to current suitability [14].

For procedural knowledge, studies on the procedural knowledge of prospective teachers in Indonesia discuss that the factor of teachers teaching many subjects and focusing on pedagogical knowledge causes the application of in-depth teaching approaches in building students' procedural knowledge cannot be adequately implemented [43]. This lack of application of procedural knowledge is driven by weaknesses in designating and selecting appropriate and sufficient teaching aids for providing mathematics models with current topics.

Meanwhile, a theoretical study with the development of the CAMIL model (Cognitive Affective Model of Immersive Learning) shows that the use of immersive virtual reality can strengthen factual, conceptual, and procedural knowledge and knowledge transfer based on the factors present in the model [27]. In other words, the features present in the use of technology can cause changes in conceptual and procedural knowledge simultaneously. Based on the conceptual and procedural knowledge study, it can be formulated that to develop this knowledge, teachers need to have an approach to building it in students. It was found that using teaching aids that allow exploration promotes further mastery of students' conceptual and procedural knowledge.

In relation to that, to address the issue of lack of guidance on the use of augmented reality in Space as well as students' mastery in the title, several theories have been referred to, such as constructivism theory, collaborative learning theory, and zones of proximal development (refer to Figure 1). In addition, van Hiele's model was used as a guide in teaching the title of Space to year 4 students. The novelty of this study is stated when the use of modules with augmented reality is used as a guide for students learning geometry. Students need to be engaged in the implementation of activities in the GeomAR3 module as well as using the tablet collaboratively, getting shared conceptual and procedural inputs, and interpreting the results through conceptual and procedural scores in the instrument given.

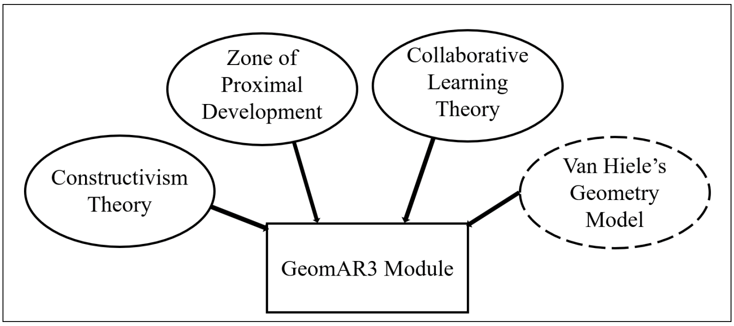


Figure 1: Theoretical framework of the study.

2 Objective

1. Determine the difference in conceptual scores (post-test and delayed post-test) between the control group students and the experimental group.
2. Determine the difference in procedural scores (post-test and delayed post-test) between the control group students and the experimental group.

3 Hypotheses

H_1 There was a significant difference in the use of modules with augmented reality in the post-test conceptual knowledge scores between the control group students and the experimental group.

H_2 There was a significant difference in the use of modules with augmented reality to the delayed post-test conceptual knowledge scores between the control group students and the experimental group.

H_3 There was a significant difference in the use of modules with augmented reality in the post-test procedural knowledge scores between the control group students and the experimental group.

H_4 There was a significant difference in the use of modules with augmented reality to the delayed post-test procedural knowledge scores between the control group students and the experimental group.

4 Methodology

4.1 Research design

This study was conducted using a quasi-experimental study design with a pre-and post-test design with a control group. To fulfil the requirements of a quasi-experimental study with a pre-test and post-test design with a control group, the researcher identifies the dependent and independent variables in this study. This study's dependent variable is the mastery level of students' conceptual and procedural knowledge. At the same time, the independent variable is the two groups involved in the study, namely the control group and the experimental group. According to Johnson and Christensen [21], a control group is a group that is not subjected to any treatment, or only standard treatment is given, while an experimental group is assigned a specific treatment that needs to be tested. In this study, the experimental group students were treated with an intervention in a module with augmented reality known as the GeomAR3 module.

In contrast, the control group students were treated with a module without augmented reality. The different interventions applied to the groups were differentiated regarding the technology approach of augmented reality in measuring students' conceptual and procedural knowledge levels. The module content regarding each intervention's components, question types, and implementation duration is replicated. The GeomAR3 module was implemented in the experimental group in mathematics class by the appointed teacher. Students used the module individually in each teaching and learning activity and were assisted by the use of tablets to scan the augmented reality functions. Students needed to be in collaborative groups of three to four to discuss the assignment. The same steps were also applied to the control group students but without the integration of augmented reality.

In this study, 59 students were involved as samples, 29 from the experimental and 30 from the control group. The samples selected had an equal distribution of students from various school performance levels. A pre-test was conducted in this study further to ensure the equality of students' existing knowledge. Control and experimental groups were taken directly from any two classes out of all the year four classes involved. The design of a quasi-experimental study is almost like an experimental study. Still, it is differentiated when random sample selection is impossible in quasi-experimental research following several factors, such as constraints in the field of study.

4.2 Research instrument

The GeomAR3 module was developed based on the ADDIE model approach (Analysis, Design, Development, Implementation, and Evaluation). The module development procedure based on the ADDIE model consists of five basic phases, namely the first phase is the needs analysis phase, the second phase is the design phase, the third phase refers to the development phase, the fourth phase is the implementation phase while the fifth phase is the assessment phase [6]. Each phase has a specific procedure and has continuity with the other phases. The findings of a phase are the starting point for the next phase in the ADDIE model [29]. The procedures of each phase are discussed comprehensively in the development of modules that integrate augmented reality technology.

The instruments in this study refer to three tests namely; (1) pre-test, (2) post-test and (3) delayed post-test. The achievement test consists of subjective questions constructed from the KSSR mathematics Year 4 syllabus by referring to the test specification index (refer to Figure 2 - 4). The achievement test set consists of 10 questions based on easy, moderate and difficult levels. The duration of each test is about one hour. Item development also adhered to Anderson's Taxonomy (1994): remember, understand, apply, analyse and evaluate. The achievement test items were determined by four experts consisting of mathematics teachers, lecturers and SISC+ regional education staff. This is to ensure that the test can measure the students' existing knowledge in the subject of Space and follow the subject requirements of mathematics for Year 4.

DRAFTING OF PRE-TEST ITEMS

Item Specification Index

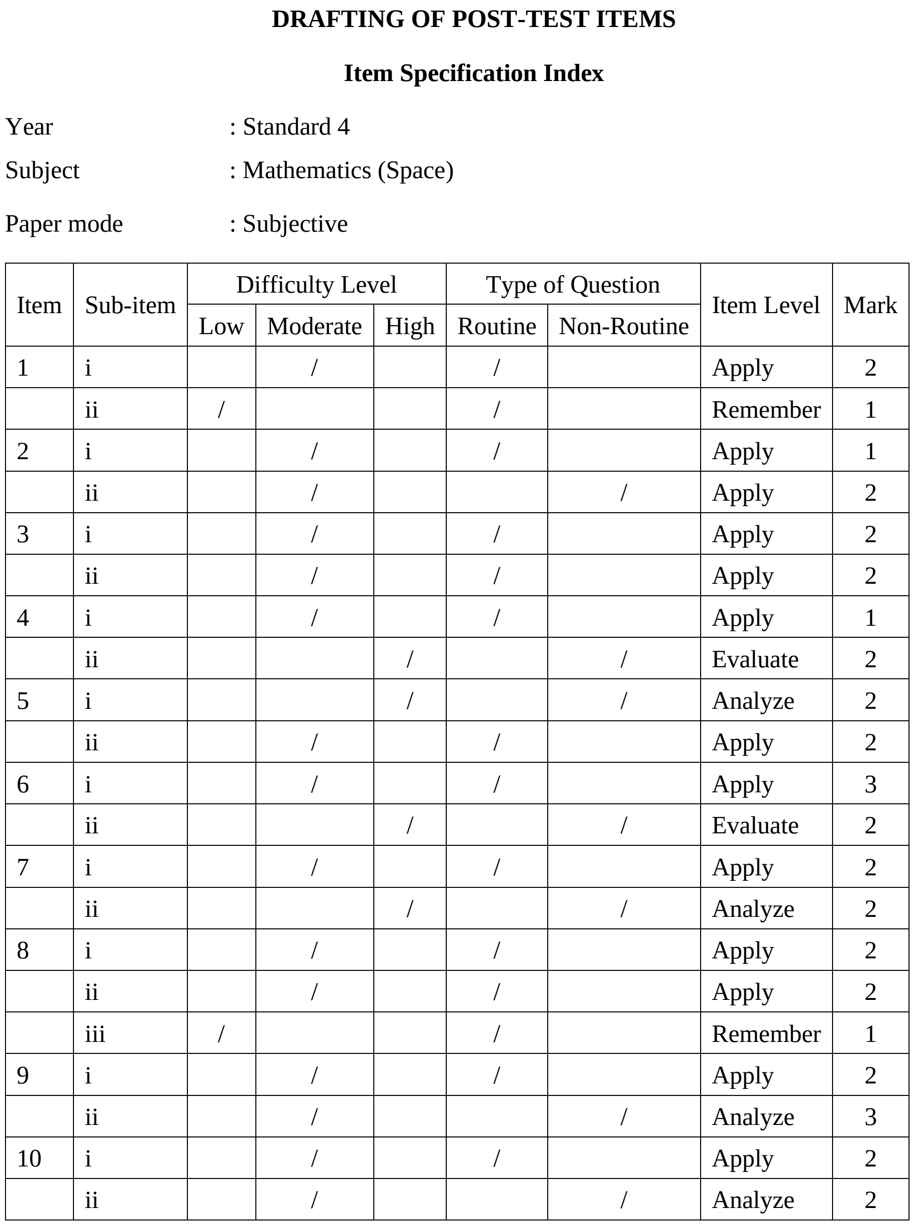
Year : Standard 4

Subject : Mathematics (Space)

Paper mode : Subjective

Item	Sub-item	Difficulty Level			Type of Question		Item Level	Mark
		Low	Moderate	High	Routine	Non-Routine		
1	i	/			/		Remember	2
	ii	/			/		Remember	2
2	i		/		/		Understand	2
	ii		/		/		Understand	2
3	i			/	/		Analyze	1
	ii		/		/		Understand	2
4	i		/		/		Apply	2
	ii		/		/		Apply	1
	iii	/			/		Understand	1
5	i			/	/		Analyze	1
	ii		/		/		Understand	2
	iii		/		/		Apply	2
6	i	/			/		Remember	1
	ii		/			/	Apply	2
7	i	/			/		Remember	1
	ii	/			/		Understand	1
			/		/		Apply	2
8	i	/			/		Remember	2
	ii	/			/		Remember	2
9	i			/	/		Analyze	1
	ii		/		/		Understand	2
			/		/		Apply	1
10	i			/		/	Evaluate	1
	ii		/			/	Apply	4

Figure 2: Item specification index for pre-test.



DRAFTING OF POST-TEST ITEMS

Item Specification Index

Year : Standard 4
Subject : Mathematics (Space)

Paper mode : Subjective

Item	Sub-item	Difficulty Level			Type of Question		Item Level	Mark
		Low	Moderate	High	Routine	Non-Routine		
1	i		/		/		Apply	2
	ii	/			/		Remember	1
2	i		/		/		Apply	1
	ii		/			/	Apply	2
3	i		/		/		Apply	2
	ii		/		/		Apply	2
4	i		/		/		Apply	1
	ii			/		/	Evaluate	2
5	i			/		/	Analyze	2
	ii		/		/		Apply	2
6	i		/		/		Apply	3
	ii			/		/	Evaluate	2
7	i		/		/		Apply	2
	ii			/		/	Analyze	2
8	i		/		/		Apply	2
	ii		/		/		Apply	2
	iii	/			/		Remember	1
9	i		/		/		Apply	2
	ii		/			/	Analyze	3
10	i		/		/		Apply	2
	ii		/			/	Analyze	2

Figure 3: Item specification index for post-test.

DRAFTING OF DELAYED POST-TEST ITEMS

Item Specification Index

Year : Standard 4
Subject : Mathematics (Space)
Paper mode : Subjective

Item	Sub-item	Difficulty Level			Type of Question		Item Level	Mark
		Low	Moderate	High	Routine	Non-Routine		
1	i		/		/		Apply	2
	ii	/			/		Understand	1
2	i		/		/	/	Apply	2
	ii		/				Remember	1
3	i		/		/		Apply	2
	ii		/		/		Apply	2
4	i		/		/		Apply	1
	ii			/		/	Evaluate	2
5	i			/		/	Analyze	2
	ii		/		/		Apply	2
6	i		/		/	/	Apply	3
	ii			/			Evaluate	2
7	i		/		/		Apply	2
	ii			/			Analyze	2
8	i		/		/		Apply	2
	ii		/		/		Analyze	2
	iii	/			/		Remember	1
9	i		/		/		Apply	2
	ii		/			/	Analyze	3
10	i		/		/		Apply	2
	ii		/				Analyze	2

Figure 4: Item specification index for delayed post-test.

4.3 Procedures of data analysis

The study's results were collected through the conduct of pre-test, post-test, and delayed post-test. However, this study used the pre-test as a covariate to reduce the threat to the overall study result. The researchers set a scoring rubric to assess conceptual and procedural knowledge according to specific scores. The conceptual knowledge rubric outlines a score of 0 to a score of 4 to indicate the level at which students interpret problem-solving questions to answer writing. Among the criteria identified in each accepted answer is how the student outlines the question's intention, roots the understanding through the question's intention, and shows the calculation path following the interpretation. The same method was followed in identifying the score for procedural knowledge. The researchers outlined a score of 0 to 4 in determining students' procedural knowledge. Procedural knowledge is investigated through the continuity of conceptual interpretations of questions to the participation of working procedures to obtain answers. This includes using symbols, numbers, units, and algorithms to solve problems.

The analysis of the study was carried out quantitatively using SPSS (Statistical Package for Analyzing Data) version 27. Descriptive analysis was carried out to find the mean score and the standard deviation for the conceptual and procedural scores of the achievement test. Inferential analysis was conducted in ANCOVA with independent samples to identify significant differences in using the GeomAR3 module with augmented reality on the mean scores of conceptual and procedural knowledge between the experimental and control groups in the post-test and the delayed post-test. In contrast, the pre-test conceptual and procedural knowledge mean scores were controlled in this analysis. Control over the pre-test conceptual and procedural knowledge scores is necessary to minimize the threat of statistical regression in this quasi-experimental study. This is because the pre-test conducted before the intervention could affect the conceptual and procedural knowledge scores in the post-test and the delayed post-test. The probability of students remembering the question structure in the pre-test causes the score to be biased hence affecting the overall study results. At the same time, extreme scores in the pre-test could potentially impact conceptual and procedural knowledge mean scores in the post-test and delayed post-test.

5 Result

5.1 Analysis of data

The initial data mapping analysis was carried out to ensure that the data distribution was normal. This is because the requirement for conducting ANCOVA analysis is that the data must be normally distributed [10]. Normal data is when most data are distributed close to the mean score. For this study, the analysis of data normality is known by running a normality test by identifying the values of skewness and kurtosis.

5.2 Measurement of data normality

Data normality measures were applied to the conceptual scores and procedural scores of the test. To test whether the data is normal, a test of skewness and kurtosis measurements was conducted. Normal values of skewness and kurtosis are within ± 1.96 [10]. Table 1 shows the skewness and kurtosis value results for the tests. Therefore, all the test results show the skewness and kurtosis values are within the range allowed to indicate normal data.

Table 1: Skewness and kurtosis value.

Test	**Skewness**	**Kurtosis**
Conceptual post-test	−0.379	−1.043
Conceptual delayed post-test	0.006	−1.371
Procedural post-test	−0.372	−1.001
Procedural delayed post-test	0.007	−1.355

Subsequently, Levene's test was used to determine the homogeneity of the variance assumption. Table 2 shows that Levene's test result, $F(1, 51) = 1.332$, $p = .254 > .05$ is insignificant and indicates no non-compliance with the requirement of homogeneity of variances.

Table 2: Levene's test of conceptual post-test after using GeomAR3 module following the group of student.

	F	$df1$	$df2$	**Sig.**
Conceptual post-test	1.332	1	52	.254

The next step was to conduct a homogeneity of variance test. The Levene's test results show that $F(1, 51) = 2.367, p = .130 > .05$ is insignificant (refer to Table 3) and this indicates no violation of the test condition of equality of variances.

Table 3: Levene's test of conceptual delayed post-test after using GeomAR3 module following the group of student.

	F	$df1$	$df2$	**Sig.**
Conceptual delayed post-test	2.367	1	52	.130

The Levene's test results show that there is no unequal variance condition with $F(1, 51) = 3.077$, $p = .085 > .05$ (see Table 4).

Table 4: Levene's test of procedural post-test after using GeomAR3 module following the group of student.

	F	$df1$	$df2$	**Sig.**
Procedural post-test	3.077	1	52	.085

Afterwards, Levene's test was performed to determine the assumption of homogeneity of variances. The test showed no violation of the assumption of the equality of variances with $F(1, 51) = 2.327, p = .133 > .05$ (refer to Table 5).

Table 5: Levene's test of procedural delayed post-test after using GeomAR3 module following the group of student.

	F	$df1$	$df2$	**Sig.**
Procedural delayed post-test	2.327	1	52	.133

ANCOVA analysis showed there was a significant difference between the mean scores of the control group students and the experimental group on the post-test conceptual knowledge score, $F(1, 51) = 48.437, p = .000 < .05$. Eta squared $= .487$, indicating a large effect size. Therefore, the study hypothesis (H_1) failed to be rejected. This result shows that using modules with augmented reality in teaching and learning geometry helps students obtain better conceptual knowledge scores than control group students.

The next step was to determine whether there was a difference in conceptual knowledge scores for the delayed post-test. Overall, there was a significant difference in the conceptual knowledge mean score of the delayed post-test between the control group students and the experimental group, $F(1,51) = 20.618, p = .000 < .05$, eta squared = .288. This indicates a large effect size, as per Cohen (1988). Therefore, the study's hypothesis (H_2) failed to be rejected. This proves that using modules with augmented reality can help students' concept mastery in the post-test compared to the control group.

ANCOVA analysis also showed a significant difference between the post-test procedural knowledge mean scores for the control group students and the experimental group, $F(1,51) = 42.631, p = .000 < .05$, eta squared = .455 (effect size is large). Thus, the study's hypothesis (H_3) failed to be rejected. This result indicates that using modules with integrated reality applications helped students score better on procedural knowledge in the post-test compared to the control group.

Besides, the ANCOVA inference analysis also showed that there was a significant difference between the mean scores of the control group students and the experimental group on the procedural score of the delayed post-test with $F(1,51) = 19.308, p = .000 < .05$, eta power of two $= .275$ (effect size is large). Therefore, the study's hypothesis (H_4) failed to be rejected. Thus, the procedural knowledge of students who went through teaching and learning using modules with augmented reality is significantly better than that of the control group in the post-test. The results of this study with ANCOVA analysis are summarised in Table 6.

Table 6: Summary of research results.

Source	**Type III Sum Squares**	*df*	**Mean**	*F*	**Sig.**	**Partial Eta Squared**
Conceptual post-test	11806.953	1	11806.953	48.437	.000	.487
Conceptual delayed post-test	5409.963	1	5409.963	20.618	.000	.288
Procedural post-test	10607.247	1	10607.247	42.631	.000	.455
Procedural delayed post-test	5159.608	1	5159.608	19.308	.000	.275

6 Discussion

Conceptual knowledge is a basic knowledge construct that includes abstract relationships, principles, categories, and representations. Conceptual knowledge is closely related to the understanding and confirmation of the principles of a topic. In this study, experimental group students showed higher conceptual knowledge scores than control group students. This is due to several external factors, such as students' self-confidence in solving problems. However, self-confidence developed because the experimental group students mastered the concept of geometry well through the intervention of modules with augmented reality. Compared to the control group, students with no AR in the module were less confident in interpreting conceptual understanding. This is because the AR module consists of activities to reinforce students' concepts through structured and continuous activities between virtual and real settings. This encourages students' exploration in geometry when they can visualise shapes interactively and in multiple dimensions.

This result is in line with the outcome of Cai et al. [7], who found that students with high self-efficacy can apply conceptual knowledge and understand and show critical thinking in mathematics, which is different from students with low self-efficacy. The perception of the experimental students' ability was further strengthened when they could present in front of the class to enlighten the geometry concepts they mastered by integrating augmented reality through the given module. The experimental students utilised their learning experience with technology while explaining their conceptual understanding of geometry through the activities and questions given in the module. Consistent with this result, it shows that the application of augmented reality used in teaching and learning serves as a medium to reinforce the basic concepts that students have mastered and then support conceptual knowledge related to dimensions, shapes, sides, and surfaces of geometric shapes [37]. The findings also discuss that augmented reality offers an immersive learning experience when students tend to have memory retention through visualization activities of basic concepts [16]. Separate studies also suggest that modeled interventions can help to improve better students' conceptual knowledge [32].

In this study, hypotheses one (H_1) and two (H_2) showed positive results on the conceptual scores of experimental group students. The experimental group students were introduced to the concepts of perimeter, area, and volume with the help of a module with augmented reality applications, as in Figure 5. The students had the opportunity to reapply the concept in a group to feel the visual experience through the impact of augmented reality and then understand the concept themselves. When the basic concepts of students have been strengthened through the technological approach, it is easy for students to connect with formulas and solve problems at a higher level.

Compared to the control group, students given the Geom3 module with a specific diagram, as in Figure 6, students can draw two-dimensional shapes only from the shape shown. The control group's students learned the concept through the teacher's explanation on the blackboard. They did not have the opportunity to reapply the understanding with technology that serves as reinforcement of the concept.

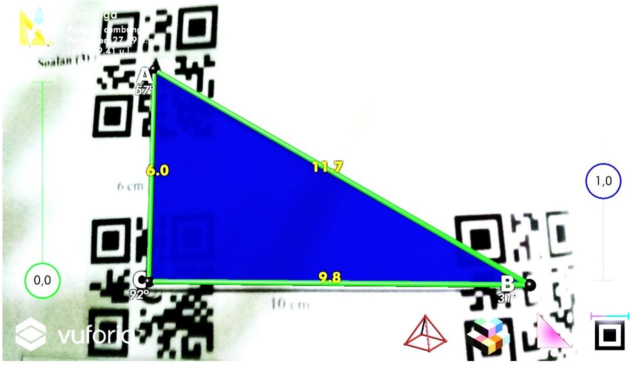


Figure 5: Conceptual knowledge approach to the experimental group.

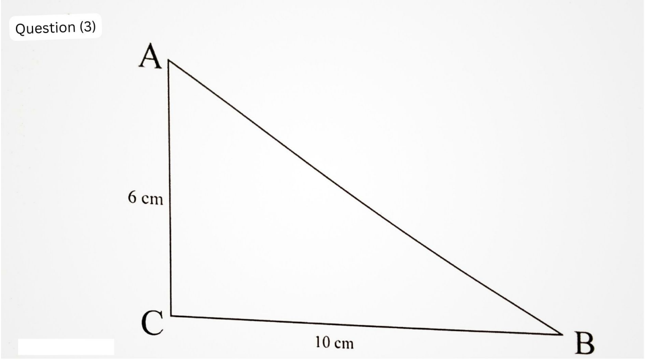
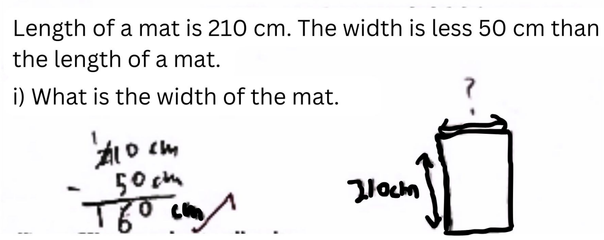


Figure 6: Conceptual knowledge approach to the control group.

Figure 7 shows the calculation results of the experimental group of students who mastered the conceptual question well. This student sketched the shape according to his understanding of the question. Instead, the student can identify and solve the question's intention correctly. Subsequently, it allows students to get a total conceptual score for how the answer is shown. Compared to the work of the students in the control group (Figure 8), this student was unable to understand the concept of perimeter because the way of calculation led to solving the area problem. This shows that the conceptual knowledge of the control group students still does not thoroughly cover the topics in the field of geometry. Therefore, students did not get a conceptual score for this question due to errors in understanding the concept.



Length of a mat is 210 cm. The width is less 50 cm than the length of a mat.

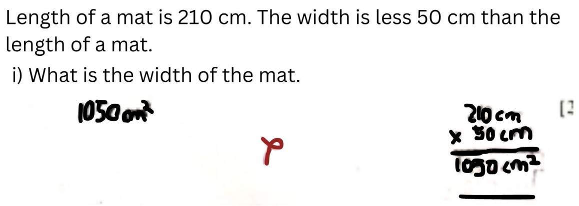
i) What is the width of the mat.

?

$$\begin{array}{r} 210\text{ cm} \\ -\ \ 50\text{ cm} \\ \hline 160\text{ cm} \end{array}$$ ✓

210cm

Figure 7: Conceptual score in a test by the experimental group.



Length of a mat is 210 cm. The width is less 50 cm than the length of a mat.

i) What is the width of the mat.

1050cm²

$$\begin{array}{r} 210\text{ cm} \\ \times\ \ 50\text{ cm} \\ \hline 1050\text{ cm}^2 \end{array}$$

Figure 8: Conceptual score in a test by control group.

Good conceptual knowledge allows students to re-express related information such as principles, constructs, characteristics, relationships, or formulas to show understanding of a question. Understanding conceptual knowledge will enable students to make judgments in solving high-level geometry problems, especially when it involves non-routine questions. Although conceptual knowledge is not necessarily positively related to student achievement, students can use the right concepts to get answers to given problem-solving questions.

Procedural knowledge is a series of representations of students' understanding in sequence according to the learned algorithm. Procedural measurement in this study is carried out by checking how students write the calculation method of a given problem-solving question. Traditionally, procedural knowledge goes in conjunction with conceptual knowledge. Students with a good procedural knowledge score tend to show a similar conceptual knowledge score due to the practice of teaching, learning, and knowledge building in the classroom [32]. The experimental group students' procedural knowledge scores were significantly better than the control group students. Hence, it positively answers hypotheses three (H_3) and four (H_4). The good grasp of students' procedural knowledge in the experimental group occurred following the factor that students could focus their full attention on learning using the augmented reality application. The Solidos RA application serves as an answer key indicator. It allows students to check the answers to the procedural calculations in solving geometry problems with answer suggestions provided in their respective smart devices (refer to Figure 9). The immersive experience of using the device to see the impact of augmented reality is a hands-on activity that makes students precise in determining answers based on the shape scans performed.

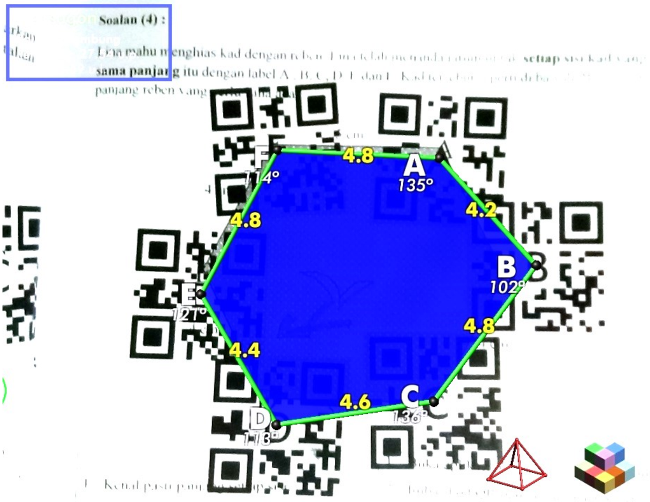
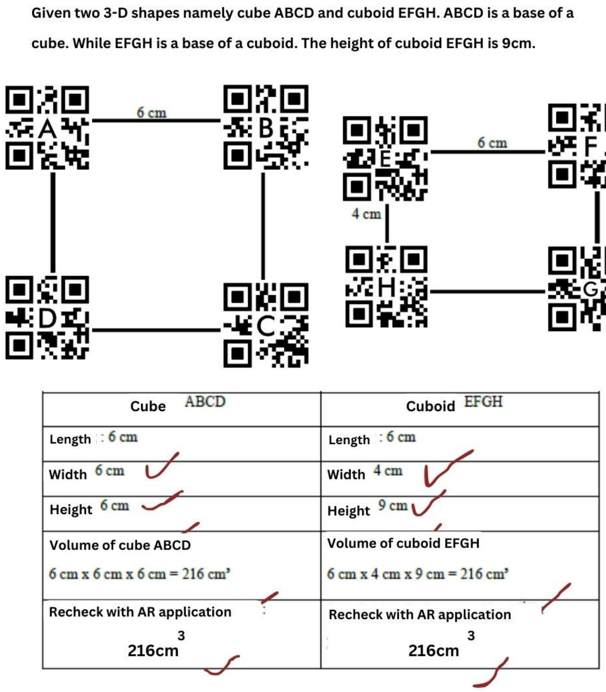


Figure 9: Answer suggestion by augmented reality application.

In line with the study findings, Makransky and Petersen [27] stated that students who focus on teaching and learning promote learning by acquiring facts, conceptual and procedural knowledge, and practical lessons. Surif et al. [42] explained that there is a simple relationship between problem-solving skills and conceptual and procedural knowledge. This shows that students who score in problem-solving mostly also show equal conceptual and procedural scores. Concerning that, a study of implementing the 9E cycle learning module with the integration of augmented reality showed that the mean score of problem-solving proficiency increased in the experimental group compared to the control group [17].

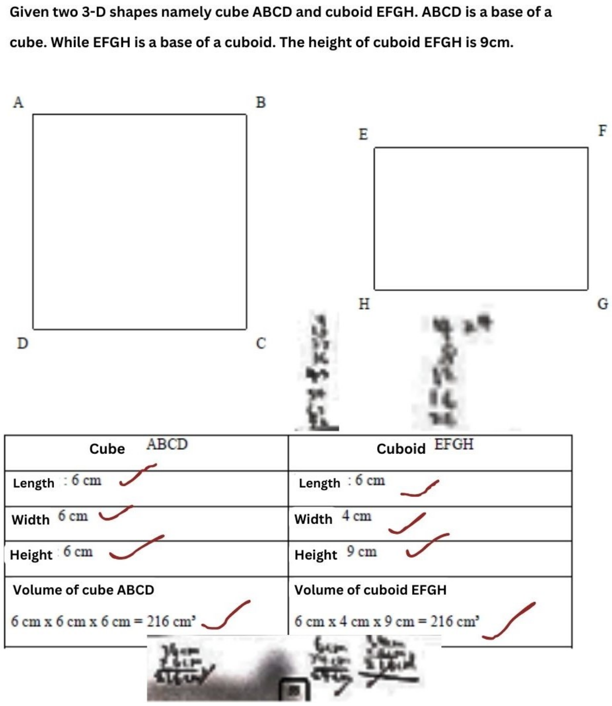
This study is consistent with the results of studies that lead to the effectiveness of augmented reality modules on problem-solving skills interconnected with students' procedural knowledge. However, the results of this study do not touch on the variables of problem-solving skills; instead, they focus on students' conceptual and procedural understanding of Spatial geometry. Students in the experimental group (a) (see Figure 10) and control group (b) (see Figure 11) were seen to be able to show step-by-step calculations following the volume formula correctly. The procedure given in the module is complete and consecutive, starting with extracting the shape's length, width, and height information, stating the formula, showing the calculation, and then writing the answer along with the correct units.



Given two 3-D shapes namely cube ABCD and cuboid EFGH. ABCD is a base of a cube. While EFGH is a base of a cuboid. The height of cuboid EFGH is 9cm.

Cube ABCD	**Cuboid** EFGH
Length : 6 cm	**Length** : 6 cm
Width 6 cm ✓	**Width** 4 cm ✓
Height 6 cm ✓	**Height** 9 cm ✓
Volume of cube ABCD 6 cm x 6 cm x 6 cm = 216 cm³	**Volume of cuboid EFGH** 6 cm x 4 cm x 9 cm = 216 cm³
Recheck with AR application **216cm^3** ✓	**Recheck with AR application** **216cm^3** ✓

Figure 10: Procedural knowledge-building approach by the experimental group.



Given two 3-D shapes namely cube ABCD and cuboid EFGH. ABCD is a base of a cube. While EFGH is a base of a cuboid. The height of cuboid EFGH is 9cm.

Cube ABCD	**Cuboid** EFGH
Length : 6 cm ✓	**Length** : 6 cm ✓
Width 6 cm ✓	**Width** 4 cm ✓
Height 6 cm ✓	**Height** 9 cm ✓
Volume of cube ABCD 6 cm x 6 cm x 6 cm = 216 cm³ ✓	**Volume of cuboid EFGH** 6 cm x 4 cm x 9 cm = 216 cm³ ✓

Figure 11: Procedural knowledge-building approach by the control group.

However, in the test (see Figure 12 and 13), the experimental group (a) students could show how to calculate the perimeter, from the sketch to the interpretation of the question they understood. The experimental group students then listed the multiplication of the number five times based on the number of sides of the shape. The calculations performed were accepted for a total score which showed the students could apply the understanding of the shape characteristics with the procedural analyses performed. Whereas for the control group (b), the student could not master the basic concept, leading to the wrong formula, indicating a calculation path that was also not worthy of a procedural score.

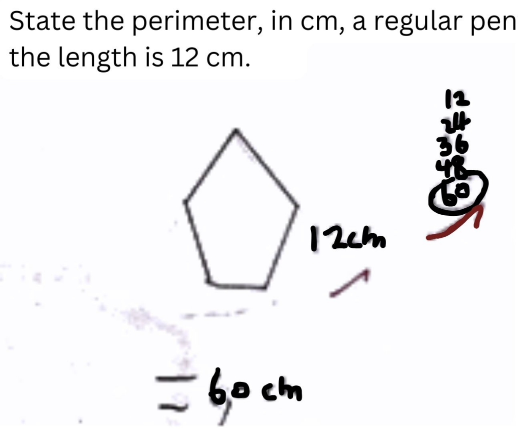

State the perimeter, in cm, a regular pentagon with one of the length is 12 cm.

Figure 12: Procedural knowledge scoring by the experimental group.

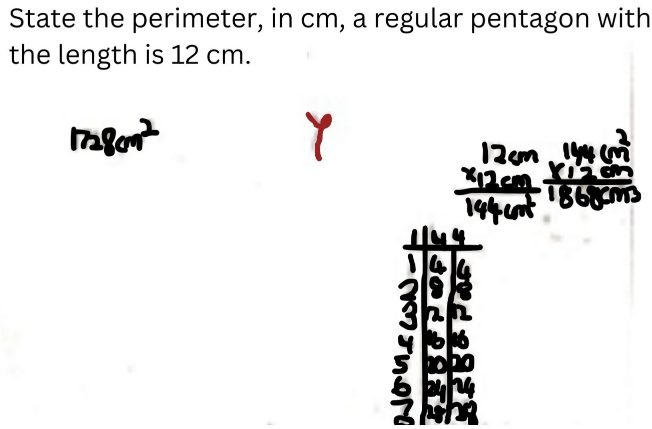

State the perimeter, in cm, a regular pentagon with one of the length is 12 cm.

Figure 13: Procedural knowledge scoring by control group.

Thus, to ensure students can score in procedural knowledge, students need to have solid conceptual knowledge at the beginning. Solid concepts encourage students to use the proper steps to solve a given problem. However, using correct procedures must be followed by basic operation skills to get the correct answer to the question.

Modules developed with the integration of augmented reality show efficacy in teaching and learning in real-time or virtual. Armed with personal smart devices, modules with augmented reality can be run in a ubiquitous learning manner to keep up with the rapidness of the digital world from time to time. The GeomAR3 module also has positive implications for students in terms of learning opportunities with devices that have augmented reality applications. Students can develop concept knowledge in a more interesting and multidimensional way. Students need to become actively involved to gain knowledge due to the collective implementation of the module. In summary, the use of modules promotes learning to take place effectively, improves student achievement and allows teaching sessions to be conducted according to the level of students' abilities, indirectly giving teachers the opportunity to develop modules with the right procedures.

7 Limitation

The limitation of the study is that the researcher did not build his application to display augmented reality. However, the researcher uses free applications available in any Android or iOS store. The investigator has also contacted the application developer to fulfil the research's ethics and requested permission to use the application developed in this study. Future study recommendations may be run with the researcher building the application using the adopted language to make it more suitable and easy to control and understand. In addition, self-built applications are more likely to fulfil the characteristics expected by the researcher despite the time and money required to develop them.

The next limitation is the inability to make generalisations in the study findings. This is because the purposeful sampling only focuses on a small sample size, namely year 4 students in a school. As such, generalisations can only be made to year 4 students who have similar characteristics in terms of background and socio-economic stage. In addition, the researcher sampled from an intact group and not all students had an equal chance of being selected even from among year 4 students in the same school. Only students from the selected classes were sampled for the study and no judgement in sample selection was applied.

8 Conclusion

Overall, the experimental group students showed significantly better conceptual knowledge scores in the post-test and delayed post-test than the control group students. This indicates that using applications with augmented reality in geometry learning positively impacts students' conceptual knowledge. Students gain a deeper conceptual understanding and retain long-term memory of the concepts learned, especially in geometry learning. The procedural knowledge scores also showed that experimental group students dominated in the post-test and delayed post-test compared to control group students. Indirectly, it shows that learning with augmented reality applications positively impacts students' mastery of algorithms in solving geometry problems. Hands-on activities in using devices while manipulating the images of geometric shapes and the visualization of the impact of augmented reality during learning allow students to master conceptual and procedural skills well.

Good conceptual knowledge allows students to reproduce relevant information such as constructs principles, characteristics, relationships, or formulas to show understanding of a question. Mastery of conceptual knowledge allows students to reason when solving high-level spatial problems, especially when non-routine questions are involved. Although conceptual knowledge is not necessarily positively related to student achievement, students can use the right concepts to get answers to given problem-solving questions. However, to ensure students can score in procedural knowledge, they need to have solid conceptual knowledge at the base. This is because solid concepts encourage students to use the right steps in solving a given problem. However, the correct procedures must be followed by basic operation skills to get the right answer to the question.

Acknowledgement The researcher would like to acknowledge the cooperation given by all the participants of this study, the supervisory committee, and the sponsors, namely the Sponsorship Department, Ministry of Education Malaysia.

Conflicts of Interest The authors declare no conflict of interest.

References

[1] M. Abdinejad, C. Ferrag, H. S. Qorbani & S. Dalili (2021). Developing a simple and cost-effective markerless Augmented Reality tool for chemistry education. *Journal of Chemical Education*, *98*(5), 1783–1788. https://doi.org/10.1021/acs.jchemed.1c00173.

[2] R. B. Armah & P. S. Kissi (2019). Use the van Hiele theory in investigating teaching strategies used by the college of education Geometry tutors. *Eurasia Journal of Mathematics, Science and Technology Education*, *15*(4), em1694. https://doi.org/10.29333/ejmste/103562.

[3] M. Arvanitaki & N. Zaranis (2020). The use of ICT in teaching Geometry in primary school. *Education and Information Technologies*, *25*(6), 5003–5016. https://doi.org/10.1007/s10639-020-10210-7.

[4] S. Badge & T. Dhote (2021). Introduction of augmented and virtual reality in the growing education sector: A review. *International Journal of Modern Agriculture*, *10*(2), 181–188. https://www.modern-journals.com/index.php/ijma/article/view/739.

[5] T. B. Bedada & M. F. Machaba (2022). The development of the cycle model and its effect on mathematics learning using GeoGebra mathematical software. *Education Inquiry*, pp. 1–24. https://doi.org/10.1080/20004508.2022.2137260.

[6] R. M. Branch (2009). *Instructional Design: The ADDIE Approach* volume 722. Springer Science Business Media, New York, NY. https://doi.org/10.1007/978-0-387-09506-6.

[7] S. Cai, E. Liu, Y. Yang & J.-C. Liang (2019). Tablet-based AR technology: Impacts on students' conceptions and approaches to learning mathematics according to their self-efficacy. *British Journal of Educational Technology*, *50*(1), 248–263. https://doi.org/10.1111/bjet.12718.

[8] C. A. Campisi, E. H. Li, D. E. Jimenez & R. L. Milanaik (2020). Augmented Reality in medical education and training: From physicians to patients. In V. Geroimenko (Ed.), *Augmented Reality in Education. A New Technology for Teaching and Learning*, pp. 111–138. Springer, Cham, New York. https://doi.org/10.1007/978-3-030-42156-4_7.

[9] Y.-C. Chen (2019). Effect of mobile Augmented Reality on learning performance, motivation, and math anxiety in a math course. *Journal of Educational Computing Research*, *57*(7), 1698–1722.

[10] Y. P. Chua (2022). *Asas Statistik Penyelidikan (Edisi Keempat)*. McGraw-Hill Education, Malaysia.

[11] D. H. Clements, J. Sarama & A.-M. DiBiase (2003). *Engaging Young Children in Mathematics: Standards for Early Childhood Mathematics Education*. Routledge, New York 1st edition. https://doi.org/10.4324/9781410609236.

[12] P. Dhar, T. Rocks, R. M. Samarasinghe, G. Stephenson & C. Smith (2021). Augmented Reality in medical education: Students' experiences and learning outcomes. *Medical Education Online*, *26*(1), Article ID: 1953953. https://doi.org/10.1080/10872981.2021.1953953.

[13] S. A. M. Elsayed (2022). The effectiveness of learning mathematics according to the STEM approach in developing the mathematical proficiency of second graders of the intermediate school. *Education Research International*, *2022*, Article ID: 5206476. https://doi.org/10.1155/2022/5206476.

[14] A. Erdogan (2017). Examining pre-service mathematics teachers' conceptual structures about "Geometry". *Journal of Education and Practice*, *8*(27), 65–74. https://eric.ed.gov/?id=ED578031.

[15] M. Flores-Bascuñana, P. D. Diago, R. Villena-Taranilla & D. F. Yáñez (2020). On Augmented Reality for the learning of 3D-geometric contents: A preliminary exploratory study with 6-grade primary students. *Education Sciences*, *10*(1), Article ID: 4. https://doi.org/10.3390/educsci10010004.

[16] S. Gargrish, D. P. Kaur, A. Mantri, G. Singh & B. Sharma (2021). Measuring effectiveness of Augmented Reality-based Geometry learning assistant on memory retention abilities of the students in 3D Geometry. *Computer Applications in Engineering Education*, *29*(6), 1811–1824. https://doi.org/10.1002/cae.22424.

[17] A. R. Hakim, M. Asikin & A. Nurcahyono (2021). The development of a learning module with mobile Augmented Reality based on a 9E learning cycle to improve problem-solving skills. *Unnes Journal of Mathematics Education Research*, *10*(1), 1–9.

[18] E. İbili, M. Çat, D. Resnyansky, S. Şahin & M. Billinghurst (2019). An assessment of Geometry teaching supported with Augmented Reality teaching materials to enhance students' 3D Geometry thinking skills. *International Journal of Mathematical Education in Science and Technology*, *51*(2), 224–246. https://doi.org/10.1080/0020739X.2019.1583382.

[19] N. Ishartono, A. Nurcahyo & I. D. Setyono (2019). Guided discovery: An alternative teaching method to reduce students' rote learning behavior in studying geometric transformation. *Journal of Physics: Conference Series*, *1265*(1), Article ID: 012019. https://doi.org/10.1088/1742-6596/1265/1/012019.

[20] H. Ismail, A. H. Abdullah, N. Syuhada & N. H. Noh (2020). Investigating student's learning difficulties in shape and space topic: A case study. *International Journal of Psychosocial Rehabilitation*, *24*(5), 5315–5321. https://doi.org/10.37200/ijpr/v24i5/pr2020238.

[21] R. B. Johnson & L. Christensen (2014). *Educational Research Quantitative, Qualitative and Mixed Approaches*. SAGE Publication, USA 5th edition.

[22] T. Khan, K. Johnston & J. Ophoff (2019). The impact of an Augmented Reality application on the learning motivation of students. *Advances in Human-Computer Interaction*, *2019*, Article ID: 7208494. https://doi.org/10.1155/2019/7208494.

[23] K. Y. Klau, M. M. L. Siahaan & J. E. Simarmata (2020). An identification of conceptual and procedural understanding: Study on preservice secondary mathematics teacher. *Al-Jabar: Jurnal Pendidikan Matematika*, *11*(2), 339–350. https://doi.org/10.24042/ajpm.v11i2.7310.

[24] J. M. Krüger, K. Palzer & D. Bodemer (2022). Learning with Augmented Reality: Impact of dimensionality and spatial abilities. *Computers and Education Open*, *3*, Article ID: 100065. https://doi.org/10.1016/j.caeo.2021.100065.

[25] B. P. Kurikulum (2018). *Dokumen Standard Kurikulum dan Pentaksiran KSSR Matematik Tahun 4*. Kementerian Pendidikan Malaysia, Malaysia.

[26] J. T. Maffei (2020). *The Effect of Augmented Reality on Learning in the Mathematics Classroom*. PhD thesis, Liberty University, Lynchburg, VA.

[27] G. Makransky & G. B. Petersen (2021). The cognitive affective model of immersive learning (CAMIL): A theoretical research-based model of learning in immersive virtual reality. *Educational Psychology Review*, *33*(3), 937–958. https://doi.org/10.1007/s10648-020-09586-2.

[28] A. Martin-Gonzalez, A. Chi-Poot & V. Uc-Cetina (2016). Usability evaluation of an Augmented Reality system for teaching euclidean vectors. *Innovations in Education and Teaching International*, *53*(6), 627–636. https://doi.org/10.1080/14703297.2015.1108856.

[29] S. J. McGriff (2000). Instructional system design (ISD): Using the ADDIE model. *Retrieved June*, *10*(2003), 513–553.

[30] A. S. Md Yunus, A. F. Mohd Ayub & T. T. Hock (2019). Geometric thinking of malaysian elementary school students. *International Journal of Instruction*, *12*(1), 1095–1112. https://eric.ed.gov/?id=EJ1201177.

[31] M. J. N. Mendezabal & D. J. C. Tindowen (2018). Improving students' attitude, conceptual understanding, and procedural skills in differential calculus through Microsoft mathematics. *Journal of Technology and Science Education*, *8*(4), 385–397. https://doi.org/10.3926/jotse.356.

[32] M. A. M. Mokhtar (2021). *Keberkesanan Modul Penyelesaian Masalah Berayat Terhadap Pencapaian Murid Tahun Empat Dalam Matematik Sekolah Rendah*. PhD thesis, Universiti Putra Malaysia, Malaysia.

[33] M. A. Naufal, A. H. Abdullah, S. Osman, M. S. Abu & H. Ihsan (2021). The effectiveness of infusion of metacognition in van Hiele model on secondary school students' Geometry thinking level. *International Journal of Instruction*, *14*(3), 535–546. https://doi.org/10.29333/iji.2021.14331a.

[34] Z. Nugraheni, B. Budiyono & I. Slamet (2018). Upgrading Geometry conceptual understanding and strategic competence through implementing rigorous mathematical thinking (RMT). In *Journal of Physics: Conference Series*, volume 983 pp. 012121. https://doi.org/10.1088/1742-6596/983/1/012121.

[35] M. Pedaste, G. Mitt & T. Jürivete (2020). What is the effect of using mobile Augmented Reality in K12 inquiry-based learning? *Education Sciences*, *10*(4), Article ID: 94. https://doi.org/10.3390/educsci10040094.

[36] N. Riastuti, M. Mardiyana & I. Pramudya (2017). Analysis of students Geometry skills viewed from spatial intelligence. In *AIP Conference Proceedings*, volume 1913 pp. Article ID: 020024. https://doi.org/10.1063/1.5016658.

[37] V. Rossano, R. Lanzilotti, A. Cazzolla & T. Roselli (2020). Augmented Reality to support Geometry learning. *IEEE Access*, *8*, 107772–107780. https://doi.org/10.1109/ACCESS.2020.3000990.

[38] F. Saadati, R. Ahmad Tarmizi, A. F. Mohd Ayub & K. Abu Bakar (2015). Effect of internet-based cognitive apprenticeship model (i-CAM) on statistics learning among postgraduate students. *PloS ONE*, *10*(7), Article ID: e0129938. https://doi.org/10.1371/journal.pone.0129938.

[39] N. Samphantakul & S. Thinwiangthong (2019). Mathematical, conceptual understanding about Geometry of 8th-grade students in the classroom using lesson study and open approach with the geometer's sketchpad. In *Journal of Physics: Conference Series*, volume 1340 pp. Article ID: 012088. https://doi.org/10.1088/1742-6596/1340/1/012088.

[40] N. C. Siregar, R. Rosli & S. M. Maat (2020). The effects of a discovery learning module on Geometry for improving students' mathematical reasoning skills, communication, and self-confidence. *International Journal of Learning, Teaching and Educational Research*, *19*(3), 214–228. https://doi.org/10.26803/ijlter.19.3.12.

[41] R. B. Stovner & K. Klette (2022). Teacher feedback on procedural skills, conceptual understanding, and mathematical practices: A video study in lower secondary mathematics classrooms. *Teaching and Teacher Education*, *110*, Article ID: 103593. https://doi.org/10.1016/j.tate.2021.103593.

[42] J. Surif, N. H. Ibrahim & M. Mokhtar (2012). Conceptual and procedural knowledge in problem-solving. *Procedia - Social and Behavioral Sciences*, *56*, 416–425. https://doi.org/10.1016/j.sbspro.2012.09.671.

[43] Yurniwati & D. A. Soleh (2021). Analyzing conceptual and procedural knowledge of Geometry among prospective teachers: Indonesian perspective. In *Journal of Physics: Conference Series*, volume 1752 pp. Article ID: 012067. https://doi.org/10.1088/1742-6596/1752/1/01206.

[44] A. Žakelj & A. Klancar (2022). The role of visual representations in Geometry learning. *European Journal of Educational Research*, *11*(3), 1393–1411. https://doi.org/10.12973/eu-jer.11.3.1393.