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Effects of augmented reality application integration with computational thinking in geometry topics

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Abstract

In this article, researchers conducted a study that integrates Augmented Reality application with Computational Thinking into Geometry Topics. Three variables were measured, Computational Thinking, Visualisation Skills and Geometry Topic achievement. The study was implemented with 124 students in two different schools using quasi-experimental study design. The t-test analysis was performed to see the differences before and after the intervention between the control and treatment groups. Next, a MANCOVA was conducted to see the effectiveness of the intervention in more depth on Computational Thinking, Visualisation Skills and Geometry Topic achievement after controlling for existing knowledge factors. The results show that there is a positive effect of teaching methods using Augmented Reality applications with Computational Thinking for students in the improvement of Computational Thinking, Visualisation Skills and Geometry Topic achievement. Moreover, the results of the MANCOVA show that overall, teaching methods using Augmented Reality applications with Computational Thinking are factors in the improvement of Computational Thinking scores, Visualisation Skills and Geometry Topic achievement, which means the students' existing knowledge did not affect the results of the three dependent variables. In conclusion, this study proposed that the Computational Thinking approach with Augmented Reality application can improve Computational Thinking, Visualisation Skills and Geometry Topic achievement among students.

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1 Introduction

Augmented Reality is defined as the technology used for virtual world objects combined into the real world and appear together within the same space in real-time (Akçayır & Akçayır, 2017). Using Augmented Reality technology, Nazar et al. (2020) have explained that abstract concepts can be illustrated in a more realistic model. Mathematics is among the subjects that can benefit from computer-based technology. According to Christou et al. (2006), studies have shown that geometry topics taught using computer-based technology results in higher student achievement than conventional methods of using textbooks. This opinion is supported in the study by Mohd Fadzil & Mohd Nihra (2019), wherein the importance of conventional learning is transformed into smart device application technology to improve the quality of learning. Since understanding abstract concept is important for students, Augmented Reality technology has become important and beneficial for learning. Geometric learning requires an understanding of spatial representations that can be overcome with Augmented Reality technology (González, 2015). The low spatial visualisation ability causes many students to have problems in reasoning and problem-solving in the topic of Geometry (Abdul Halim & Effandi, 2013). According to Chinnappan and Lawson (1996), some students have experienced difficulties in solving problems because they do not use effective problem-solving strategies. The selection of learning strategies is essential since it can influence the success and effectiveness of the technology support used (Mohd Fadzil et al., 2020). Jona et al. (2014) have argued that using Computational Thinking is one of the strategies in methods for problem-solving in Mathematics. The term Computational Thinking has been widely used in practice in various fields not limited to the computer science field since the introduction of this term. According to Wing (2010), Computational Thinking is a thought process involved in formulating problems and solutions so that the solution is represented in a form that can be implemented effectively by information processing agents. Some previous studies have shown that problem solving can be overcome with the implementation of Computational Thinking in the context of mathematical subjects with positive effects.

1.1 Geometry in education

Geometry is a critical topic in mathematics that involves nature and relation between point, line, shape and space. According to Abd Rahim et al. (2018), geometry is mathematics knowledge that includes the nature of shape and space, measurement, and magnitude, and the relations of dot, line, corner and surface. Bikić et al. (2016) has explained that most students think that memorising correct answers for mathematics is important rather than thinking that mathematics is important in principle. In this regard, Bergstrom and Zhang (2016) have criticised the teaching and learning methods of geometry that use a traditional approach, and they claim that the available intervention approach used is still not enough for teaching and learning. The obvious implication is that student achievement is low due to the use of conventional curriculum which emphasizes more on the aspect of naming shapes and learning on how to write suitable symbols for simple concepts in geometry. Ayan and Isiksal Bostan (2016) have suggested the integration of technology tools in teaching activities in order to ensure students can be immersed in authentic learning experiences and be able to solve complex problems. Dynamic geometrical software, for instance GeoGebra, can assist students to visualise and imagine while conquering mathematical concepts (Effandi Zakaria & Lee, 2012). This opinion is clearly approved by Hollebrands and Okumuş(2018), who have claimed that students will pay more attention to geometry topics provided with the use of technology in the learning activities. Lee and Hollebrands (2006) have clearly elaborated that the elements available in the technological tool will help assist students to use any resources of the tool for the content and solve any mathematical problem. One of the technology tools that can help solve geometry problems is Augmented Reality technology (Radu et al., 2015).

1.2 Augmented reality in education

Augmented Reality is the latest trend in education. Jeřábek et al. (2014) has elaborated that the use of Augmented Reality in education consists of various shapes and methods that can be simplified to five educational objectives namely, to enhance the quality for information, spatial ability, phenomenon simulation, event and process, development of efficiency for modelling situation, and management activity. Based on the research by Chang and Hwang (2018), learning system approaches using Augmented Reality will positively impact student's learning achievement, learning motivation, and tendency to think creatively, and collaborative effectiveness of the teamwork has increased tremendously. According to Dünser et al. (2006), previous research has shown that the problem of visual spatial ability can be improved by the use of Augmented Reality technology. As per research conducted by Ferrer-Torregrosa et al. (2015), the development of Augmented Reality can enhance the understanding of spatial relations, and the student can achieve better scores for individual writing assessments in comparison with the use of conventional methods. Jeřábek et al. (2014) has clearly explained that Augmented Reality characteristics are beneficial especially from the visual sight perception which refers to the shape and additional information aspect that can solve cognitive difficulty to process the information which can potentially apply in the educational field. In addition to Augmented Reality technology, there is also Virtual Reality (VR) technology. Mehroosh et al. (2017) has explained that Augmented Reality adds something to the existing environment to enhance the real world, whereas Virtual Reality actually creates an entirely new artificial world. Augmented Reality needs the environment, just a camera integrated in our devices such as smartphone, tablets, or PCs will suffice. In sum, Augmented Reality is ahead of Virtual Reality, as there are already several products in the market. Virtual Reality has its limitations. Despite its ability to provide whole immersive experiences, it blocks users' interaction with the surroundings.

1.3 Visualisation skill

Visualisation is a part of spatial cognitive element by which it is one of the major categories in visual science discipline that has clearly elaborated by (Bertoline, 1998). He has clearly stated visualisation as one's expertise to build, manipulate and define all the images from one's mind. On the other hand, Nordin and Saud (2006) have clarified that visualisation as one's capability to imagine shape, pattern or specific object that the person has no experience to see the object physically, yet she has the ability to visualise. Thus, Visualisation skill can be understood as an essential aspect related to the mathematical learning process since it helps students comprehend concepts. This claim has been proposed by Klerkx et al. (2014) who believes that mathematical cognitive processes do not only need the use of representative system but cognitive coordination as well. Over time, visual teaching methods have widely expanded and covered all techniques to apply technology, but our understanding on how those visual aspects can influence learning process is still limited (Libarkin & Brick, 2002). As per variation of problem solving perspective by using application and technology, among essential skill which needs to be developed is visuospatial skill (Prokýšek et al., 2013). Depending on the characteristics of a mathematical problem that needs to be solved, students should be able to choose any of the visualisation skills. Gutiérrez (1996) has suggested that visualisation ability principle should be given consideration in the process of building geometrical software.

1.4 Computational thinking

Ever since the use of the term Computational Thinking by Jeanette Wing in 2006, various discussions have contributed to the definition of Computational thinking. Csizmadia et al. (2015) has explained that Computational Thinking assists students to solve problems, to simplify problems to the smaller pieces and to plan algorithms for solving problems. Jona et al. (2014) emphasized that the implementation of Computational Thinking in mathematics can provide understanding for students to explore and use a computational approach within a context that is easy to comprehend. Shute et al. (2017) has also explained that Computational Thinking is the basis of expected concepts to solve problems efficiently and effectively. There have been several studies that have explained the use of Computational Thinking in the process of solving problem. Among those studies, the research by (Angeli et al., 2016) has suggested a framework to help introduce the Computational Thinking concept to students. This framework has identified five essential skills in promoting Computational Thinking namely, abstraction, generalization, decomposition, algorithms (sequencing and flow of control) and debugging. Harangus and Kátai (2020) have clearly mentioned that Computational Thinking can be effective when student's cognitive ability is being considered and the ability can be expanded within the difference of learning context. In fact, Román-gonzález et al. (2019) has provided new evidence that Computational Thinking is related to cognitive abilities, such as visuospatial skills, and the ability to reason and solve problems. On the other hand, a study by Gong et al. (2020) showed that the use of Computational Thinking in learning strategies is one clear factor that can influence student's learning activity.

1.5 The relation between computational thinking, visualisation skills and geometry topic

According to Sung & Black (2020), their research has shown that Computational Thinking has a relation with problem solving in Geometrical topic. The opinion is the same with DeJarnette and González (2016) which has explained that students are more interested in Mathematics subject if the learning on problem solving is according to the real context. Among the approaches used in the problem solving is to use Computational Thinking skills as a process of solving big problems in learning (Ting Chia Hsu et al., 2018). Cuny et al. (2010) has proposed the use of Computational Thinking approach as a thinking process which will be able to provide effective problem solving. Problem-solving approach such as Computational Thinking is one of the strategies that is recognised to have competency and it is important to aid the learning process (De Souza et al., 2019).

Among the important definitions that need to be included in the Computational Thinking process are modeling, simulation and visualisation *(*National Research Council, 2010; Selby & Woollard, 2013). In fact, according to Buckley et al. (2019), Visualisation spatial skill is essential to influence problem-solving process in Geometrical topic. It is relevent with the research by Hambrusch et al. (2009) which has stated that Visualisation skill can help students to understand the questions on problem-solving related to topics in learning. In this regard, the approach using Computational Thinking should include visualisation skill mechanism according to (Repenning et al., 2017) because it can enhance students undersanding during the process of solving problem. In the research by Gutiérrez (1996) has explained that visualisation in Mathematics is one type of activity thinking which is based on the use of elements in visual or spatial, mental or physical for problem-solving or proving the nature. González (2015) also has stated that the learning objective for spacing visualisation is important because students are able to imagine any objects and able to learn about Geometry which will help them to solve any problems on Geometry topics. Liao et al. (2015) also has stated the importance to enhance the effective tools and strategies to help students learn geometrical concept and also to enhance their spatial visualisation skill.

Based on the research done by Hwang et al. (2009) has shown the technology in Geometrical learning is essential and able to help students understand problem-solving process for Geometry topic, for an instance, to use various problem-solving strategies as well as to reduce misconception to understand Geometry. The same opinion is given by Gutiérrez (1996), as referred to his research, it has shown that students are able to solve problem on Geometry with the use of software which helps them manipulate 3D Geometry object mainly for the visualisation and mental image. Among the advance technology for Geometry learning is Augmented Reality as referred to the research by (İbili & Şahin, 2016; Radu et al., 2015). Augmented Reality technology, with the ability to layer computer-generated graphic into real world object, can serve as an effective tool for learning the concept of Spatial Visualisation in Geometry learning (Liao et al., 2015). Based on the explanation, this study focuses on three variables that support each other in the learning of Geometry topic as per discussion of Computational Thinking, Visualisation Skills and Geometry Topic achievement.

2 Problem statement

Past studies, Kim and Md-Ali (2016) have shown that many students encounter problems in reasoning and problem-solving in the topic of geometry due to the low spatial visualisation ability to conceptualise the learning materials' content. According to Bergstrom and Zhang (2016), geometry has become an increasingly difficult mathematical topic for students to understand as they enter high school. This is because the topic of geometry requires higher order mathematical thinking skills in problem-solving. After all, its level of representation is more abstract (Hwang et al., 2009). According to Herbert et al. (2018), Augmented Reality assists in reducing the problem of low spatial visualisation capabilities by connecting spatial information using real-world space. Studies have proven that mental relationships with spatial visualisation capabilities become faster and more accurate for Augmented Reality users compared to non-Augmented Reality interfaces (Marner et al., 2013). In a study by Mohd Fadzil et al. (2018), students' perceptions are positive towards the usage of Augmented Reality applications in the topic of geometry. Furthermore, Augmented Reality implementation in learning can provide students skills of cognitive thinking such as problem-solving (Dunleavy et al., 2009). Whereas according to Chinnappan and Lawson (1996), some students face difficulties in solving problems since they do not use effective problem-solving strategies. According to Booker and Windsor (2010), among the thoughts needed to solve problems in the topic of geometry are Algebraic Thinking, Computational Thinking and Geometric Thinking. This opinion is supported by DeJarnette and González (2016) who stated that students are more interested in mathematics that is relevant to learn when learning is based on problem-solving in the real-world context. Among the problem solving methods used in problem-solving learning is to use Computational thinking skills as a problem-solving process in learning (Ting Chia Hsu et al., 2018).

3 Research questions

The study is conducted to investigate the following questions:

Are there significant differences for students before and after learning the topic of geometry using Augmented Reality applications with Computational Thinking features;

a. What is the level of Computational Thinking among students using Augmented Reality learning with Computational Thinking as opposed to those using conventional learning?

b. What is the level of Visualisation Skills among students using Augmented Reality learning with Computational Thinking as opposed to those using conventional learning?
c. What is students' achievement of geometry topics using Augmented Reality learning with Computational Thinking compared to those using conventional learning?

4 Conceptual framework

A conceptual framework is formed in ensuring that the learning of Augmented Reality applications with Computational Thinking is focused on the objectives of the study as illustrated in Fig. 1. The development of Augmented Reality applications is implemented with the adoption (Adopt) elements of the Augmented Reality system (Liang, 2016) for the content development purpose learning materials in the topic of Geometry using Augmented Reality technology. Subsequently, the content of Geometry Topic achievement learning materials is combined with the visualisation capability principles in the development of 3D dynamic geometry software based on (Gutiérrez, 1996). The result of combining all these principles and elements arranged in carefully and systematically in the form of a conceptual framework will produce three outputs. These are computational thinking, visualisation skills, and geometry topic achievement. Gutiérrez (1996) explained that before users can solve the problems in geometry, the resulting image will start the visual thinking process depending on some of the user's visual abilities to perform mental or other external image processing can be generated. This framework identifies five elements Angeli et al. (2016) for the Computational Thinking process which consists of abstraction, generalisation, decomposition, algorithms are divided into (sequencing and flow of control) and debugging. Based on the framework, students will develop abstraction skills by identifying important and relevant objects while generalisation

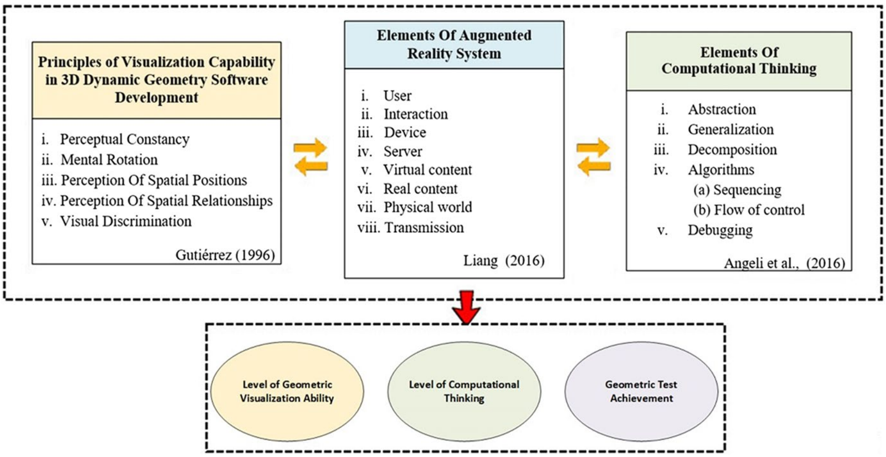


Fig. 1 Conceptual framework

by formulating solutions in generic terms in ensuring they can be applied to different problems. Next, develop the Decomposition skill to solve complex problems by breaking it into smaller parts for easier understanding. Then, algorithm thinking usage to formulate the sequence of actions of the operating set of problem-solving methods. Finally, debugging to identify and rectify issues and errors during the troubleshooting process.

5 Development and validation

The framework of Augmented Reality application development is based on instructional ADDIE (Analysis, Design, Development, Implementation and Evaluation) design model by which work process is divided to five phases: analysis, design, development, implementation and evaluation (Molenda, 2003). Each phase of ADDIE model is well organised and has helped the Augmented Reality application to be more systematic. The ADDIE model has been chosen as the instructional design and agile method respectively, to guide the design process in consideration of educational needs (Budoya et al., 2019). The ADDIE model is now technologically accepted on a large scale worldwide, and it has been researched in a plethora of studies (Almelhi, 2021). Some researchers believe this model is flexible enough to be adapted to different instructional environments and, therefore, it is strongly applicable for integrating technology into instruction (Tzu Chuan Hsu et al., 2014). Besides those ideas, according to Trentin and Alvino (2011), the ADDIE model is very useful since it is suitable as problem solving model. In fact, Jonassen (2008) has stated that ADDIE model is recognized by instructional expert as schematically and procedurally robust and in an outlined form. Table 1 shows each phase description of ADDIE Model that is used in this research. The Augmented Reality application design development method uses eight basic elements for Augmented Reality application development (Liang 2016). Eight basic elements of Augmented Reality development involves user, interaction, device, server, virtual content, real content, physical world and transmission. Unity software is chosen as a program that enables user to develop material content for Augmented Reality environment. To enable Augmented Reality material content to be easily accessed by users in the real situation or world, the Vuforia plugin is used as the server in order to detect target image via Marker in the real situation or world. The programmer used Mono Develop software. The researcher chose Android OS as the operation system for the application, which is based on popular smartphone OS among students in Malaysia. According to Li et al. (2017), there are several technologies for Augmented Reality markers, namely, single image tracker, multiple combine image tracker, object recognition, and location based tracker. In this research, researchers chose multiple combine image tracker like (Alhumaidan et al., 2018) since dynamic movement can be used by combining several image detectors, which will produce various geometrical shapes. For an instance, polygon for pentagon has five edges, thus, the combination of five markers is needed to solve the geometrical problem. Those markers can be reduced or added according to the type of polygon, namely, hexagon, heptagon,

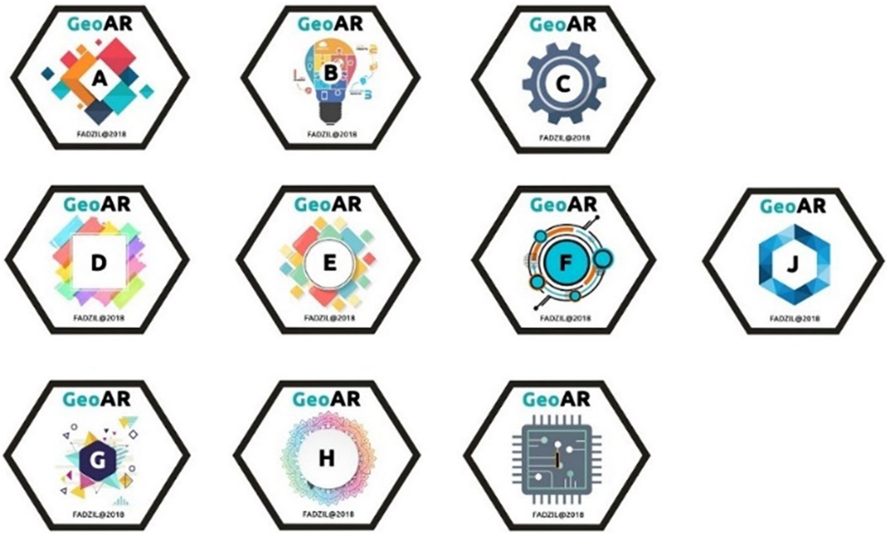


Fig. 2 Augmented Reality Markers of this research

octagon, nonagon and decagon. Figure 2 shows all those markers (Table 1; Figs. 3 and 4).

Table 2 shows the Augmented Reality Application For Technical Designing Validation has been conducted to three teachers who have given the following review:

Table 2 shows the Augmented Reality Application For Technical Designing Validation (Part 1: Presentation Designing) scores overall min of 3.81 while second, third, fourth, eleventh and twelfth items scores the highest min of 4.00.

Table 3 shows the For Augmented Reality Application Useable Validation has been conducted to 12 students who have given the following review:

Table 3 shows the Augmented Reality Application usability validation factor which is attempted by student with the overall min score of 3.87. For explanation (Designing) overall min score of 3.83 refers to first, second, third items that scores the highest min of 3.83.

6 Methodology

This study used a quasi-experimental design for the Pre-test and Post-test. According to Salkind (2010), this experimental quasi design is often used when researchers are not able to perform random selection of study samples. This opinion is supported by Creswell (2009), who stated that quasi-experimental designs can support evaluation of the effectiveness of the intervention program as a substitute for true experimental design. This study involved two interventions, learning the topic of geometry using Augmented Reality applications with Computational Thinking compared to conventional learning. Learning methods for the control group are based on conventional learning using textbooks, workbooks, and exercises. The learning method for the

Table 1 Five phases of addie model in this research

Phase	Description
Analysis	This phase is focusing on pre analysis which is conducted before learning activity and GeoAR application. This phase involves some analysis, including the selection of related subjects and learning content, user needs, software requirements and application execution
Design	This application is developed by considering the shape of Augmented Reality application development which consists of eight basic elements (Liang, 2016). The eight basic elements of Augmented Reality development are user, interaction, device, server, virtual content, actual content, physical world and transmission
Development	Unity Software is selected as main software to develop GeoAR application. Unity is a program which enables user to develop content for the Augmented Reality environment (Shown in Fig. 3). To ensure user can access Augmented Reality material content, the Vuforia plugin is used as the server to ensure the target image can be detected by marker in the actual situation. For the software for editor in script programming, the developer used Mono Develop software
Implementation	Generally, GeoAR application consists of several phases that pupil needs to go through during teaching and learning activity in the classroom. The activities are prepared according to appropriate duration for mathematics in school. The student is able to visualise the virtual polygon (Shown in Fig. 4). Thus, the difficulty with visualising geometry can be minimised. GeoAR application is also used together with Computational Thinking stimulation during and after the process
Evaluation	The phase of assessment and evaluation of content design of the GeoAR application involved four experts. Those experts consisted of one industrial expert on technology of Augmented Reality applications, one mathematics teacher of form 1 and two officers of the Resource and Educational Technology Sector, Johor State Educational Department who conducted the comprehensive evaluation. On the other hand, the phase of assessment and evaluation on the usability of GeoAR application was conducted with 12 students who were chosen based on homogeneous sample. There are seven main items that are being evaluated stated in the questionnaire for the usability of GeoAR application: Design, Functionality, Convenience, Learning Ability, Satisfaction, Outcome, and Error

treatment group is the learning process through Augmented Reality application technology with computational thinking. The study uses a quasi-experimental design because there is a comparison between two groups, namely the treatment group and the control group to see the effect and outcome after the intervention. Johnson and Christensen (2000) have explained the quasi-experimental design should have two comparison groups, namely the treatment group and the control group. Besides, this study also uses quasi-experimental design in order to consider the limitation in terms of sample selection as per reason stated by (Harris et al., 2004). Among them are (1) ethical considerations, (2) difficulty of randomizing subjects, (3) difficulty to randomize by locations (e.g., by wards), (4) small available sample size. We selected 15 students to determine through reliability values if the questions given are valid. Reliability values were obtained through Pearson correlation by comparing the first test score with the second test score. The value of the Pearson correlation coefficient for the Computational Thinking test score is r $(15)=0.776$. The value of the Pearson correlation coefficient for the Visualisation Skills test score is r $(15)=0.761$.

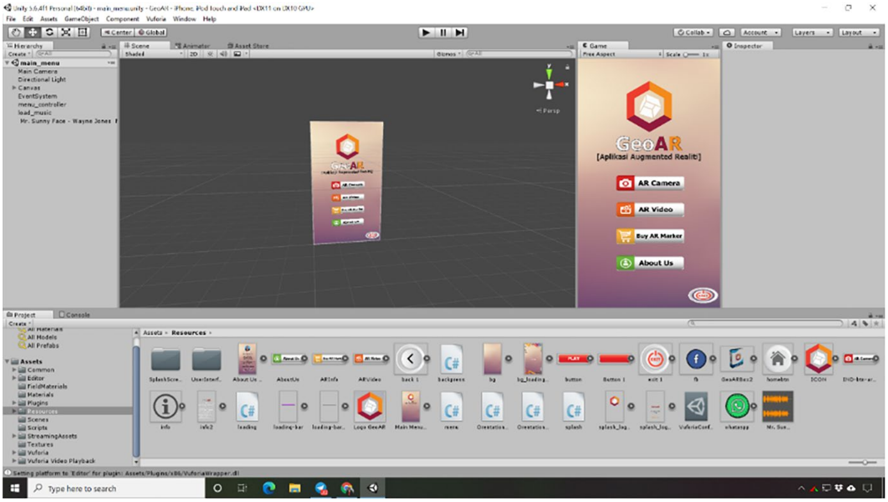


Fig. 3 Application Development Display Using Unity Software

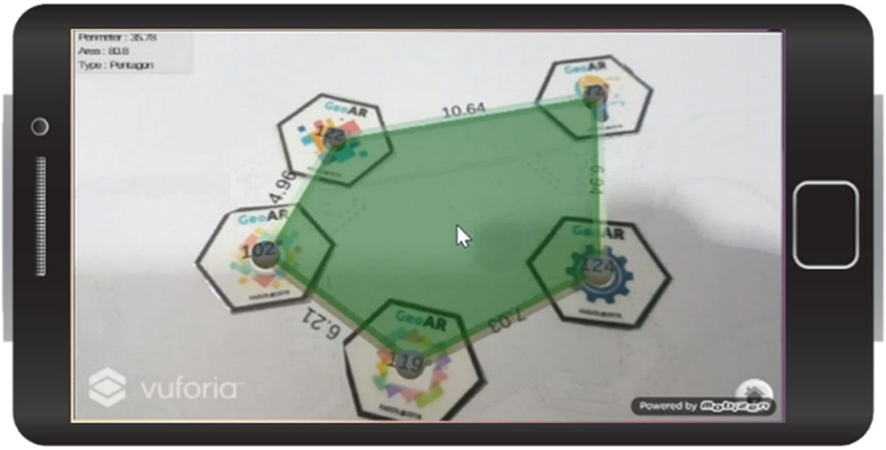


Fig. 4 Augmented Reality Geometrical Application

The value of the Pearson correlation coefficient for Geometry Topic achievement test score is r (15) = 0.934. Based on the method, according to (Akoglu, 2018; Morgan et al., 2012) the reliability value of r value above 0.7 means that the test can be accepted and applied in the actual study.

Based on Table 4, Pre-tests were performed before the intervention on the control group and the treatment group. The purpose of the Pre-test is to identify the level of Computational Thinking, the level of Visualisation Skills, and students' achievement of Geometry Topic before the intervention is implemented. The instrument used to measure Computational Thinking is an adaptation of Computational

Table 2 Augmented reality application for technical designing validation

No	Part 1: Presentation Design	Mean
1	Clear Augmented Reality application for interface designing	3.75
2	Interface designing helps attract user	4.00
3	Clear and readable text	4.00
4	Augmented Reality application has no spelling mistake	4.00
5	Interesting graphic and image	3.75
6	Suitable colour choice	3.50
7	Suitable audio used	3.75
8	Audio used does not disturb user concentration towards lesson content	3.50
9	Suitable video used	3.75
10	Video used can assist user to understand the information given	4.00
11	Suitable response time for user	3.75
12	Easily controlled for user interface	4.00
Overall Mean		3.81
No	Part II: Cognitive Theory Of Mayer Multimedia Learning	Mean
1	Augmented Reality application has pictures of 2D, 3D and wording	3.75
2	Augmented Reality application has only important facts	3.75
3	Information of main topic is exposed with various colours in application	3.75
4	Augmented Reality application contains virtual Augmented Reality graphic and narration only	3.75
5	Augmented Reality virtual item and wording are displayed near to each other in Augmented Reality application	4.00
6	Wording and picture are portrayed simultaneously in Augmented Reality application	3.75
7	Before and after buttons are available in Augmented Reality application in order to help assist students to control their self-access learning	4.00
8	Components and lables are available in Augmented Reality application	4.00
Overall Mean		3.84

Table 3 Augmented reality application useable validation

No	(Designing)	Mean
1	I such as to use Augmented Reality application interface	3.83
2	Information organisation in Augmented Reality application is clear	3.83
3	Augmented Reality application interface is interesting	3.83
Overall Mean		3.83
No	(Functionality)	Mean
1	Augmented Reality application contains all needed functions and ability	3.92
2	Information shared with Augmented Reality application is clear	3.67
3	All features in Augmented Reality application are well functioning	3.83
Overall Mean		3.81
No	(Convenience)	Mean
1	Easy to use Augmented Reality application	3.92
2	Easy to access information that I need via Augmented Reality application	3.75
3	Clear information shared by Augmented Reality application	3.83
4	Overall, Augmented Reality application is easy to use	4.00
Overall Mean		3.85
No	(Learning Ability)	Mean
1	Easy to learn via Augmented Reality application	3.92
2	No hassle to read lots of information before I can use Augmented Reality application correctly	3.83
3	Easy to understand all information shared in Augmented Reality application	3.75
Overall Mean		3.83
No	(Satisfaction)	Mean
1	I feel comfortable using Augmented Reality application	3.92
2	I enjoy exploring Augmented Reality application	3.92
3	Overall, I feel satisfied using Augmented Reality application	3.92
Overall Mean		3.92

Table 3 (continued)

No	(Outcome)	Mean
1	I believe I am more productive when I use Augmented Reality application	3.92
2	Augmented Reality application successfully makes me feel confident and enhances my skill and knowledge	3.92
3	Based on my experience using Augmented Reality application, I believe that I will always use it	4.00
Overall Mean		3.95
No	(Error)	Mean
1	When I make any mistakes while using Augmented Reality application, I can correct them easily and correctly	3.83
Overall Mean For Augmented Reality Application Usability		3.87

Table 4 Research methodology

Group	Pre-test	Intervention	Post-Test
Control	U_1	X_1	U_2
Treatment		X_2	

Thinking test (Román González, 2015), the level of Visualisation Skills is an adaptation of Minnesota Paper Form Board Test (Likert & Quasha, 1969), and the students achievement of Geometry Topic is an adaptation of a geometry topic test (Sasbadi, 2018). The post-test was performed after the intervention was implemented on both groups. The post-test was implemented to observe the effect of the intervention by comparing with the pre-test for the level of Computational Thinking, the level of Visualisation Skills, and the students achievement of Geometry Topic. The reason of using t-test analysis is mainly to compare inferential statistic by referring to the data before and after the intervention between the control and treatment groups. It is a type of inferential statistic used to study if there is a statistical difference between two groups. Mathematically, it establishes the problem by assuming that the means of the two distributions are equal (H^0: $\mu^1 = \mu^2$). If the t-test rejects the null hypothesis (H^0: $\mu^1 = \mu^2$), it indicates that the groups are highly probably different. T-tests are statistical hypothesis tests that is used to analyze one or two sample means. Depending on the t-test used, the comparison can be understood based on a sample mean to a hypothesized value, the means of two independent samples, or the difference between paired samples. The implication of the t-test analysis was performed to see the differences before and after the intervention between the control and treatment groups. This study showed that the treatment group was better in term of achievement scores for Computational thinking test, Visualisation skills and Geometry topic achievement as compared to the control group. Furthermore, the t-test analysis showed that there were significant differences, for the three tests which gave the implication that the variables in the conceptual framework as refer to Fig. 1 had a positive effect on student learning. This t-test analysis provided some empirical evidence that showed a positive impact in the intervention of Augmented Reality application with Computational thinking into Geometry Topics as per stated in Tables 8, 9, 11, 12, 14 and 15. Researcher found the combination of the result produced conceptual framework namely Augmented Reality, the principle of Visualisation ability and Computational thinking element were interdependent to produce research findings according to t-test result. The Geometry problem solving that used Computational thinking elements was based on the combination of the conceptual framework that made it functional. According to this study, the existence of Augmented Reality system, the principle of Visualisation ability and the elements of Computational thinking would open the space for reasearch and discussion widely which would help determine the integration of Geometry topic learning. As a result, it would give better impact for present educational world. Next, to study the effectiveness of the intervention we used a t-test (Cohen's d). Based on Cohen (1988), referring to ($d > 0.80$) has proposed the value of the effect of the intervention is large. Next, power analysis is conducted to determine the treatment power based on the effect size obtained from the study. The analysis was performed using G * Power software. Data analysis is continued using Multivariate analysis of covariance (MANCOVA), which is conducted to observe intervention effectiveness (Independent Variable) towards Computational thinking, Visualisation skill and student's Geometrical topic achievement (Dependent Variable) by controlling student's existing knowledge factors. MANCOVA is a statistical technique for multiple continuous dependent variables and an independent grouping variable, while controlling for a third variable called the covariate. Covariates are added so that it can reduce error terms and so that the analysis eliminates the covariates' effect on the relationship between the independent grouping variable and the continuous grouping variable and the continuous dependent variable. Covariates can also use ratio data (Tabachnick & Fidell, 1983).

6.1 Sampling

This study used purposive sampling in a secondary school that has a *Special Plan Class*, (SPC) consisting of Form 1 students in two secondary schools in the district of Johor Bahru, Johor, Malaysia. A total of 124 students were involved in this study, with of 62 students placed in the control group, which received conventional learning while another 62 students were placed in the treatment group, which received learning intervention using Augmented Reality application with Computational Thinking. For the control group, 62 students took the Computational Thinking test, Visualisation Skills test and Geometry Topic test. Similarly, for the treatment group, 62 students took the Computational Thinking test, Visualisation Skills test and Geometry topic test. The selection of different samples in this study is to ensure that the MANCOVA can be conducted. All students involved in this study have homogeneous characteristics from the *Special Plan Class*, ensuring that the level of academic mastery is equivalent. This study is based on ethical consideration which guarantees that the identity of the participants will be kept confidential and has received permission from the Malaysian Ministry of Education and the school administration.

6.2 6.2 Research procedure

For research procedure, the control group and treatment group have different teachers. Both teachers have similar backgrounds of teaching mathematics. Therefore, teaching experience for both teachers involved is about the same. The researcher also conducted observations and discussions with two teachers during the study. This needs to be done in order to ensure both teachers are doing teaching according to the stipulated guidelines and strictly referring to the geometry Curriculum And Assessment Standard Documents, of Form 1 Mathematics per the Malaysia Ministry of Education (MOE) (Shown in Table 5). Thus, learning session of the treatment group is at par especially for the process of comparing both groups. Treatment group students receive learning activities through the Augmented Reality application with Computational Thinking based on their learning phase (Shown in Table 6). Within this phase, all students explored Augmented Reality application concepts in advance with coaching from the teacher, especially when they need assistance on with the Augmented Reality application. Within this phase, the teacher emphasizes Computational skill for solving problems in geometry. The practice is different for controlled group, for whom learning activities involve the conventional method where the concepts given use the "Chalk and Talk" method to solve geometry problems in reference to text book. The following detail is the timetable of Geometrical learning practice for both controlled and treatment groups (Tables 5 and 6).

This study is also limited to one topic in the syllabus of Mathematics form 1, namely the topic of Geometry. Therefore, the Augmented Reality application was developed for the topic of Geometry which is based on the Curriculum and Assessment Standard Document (DSKP) for the Secondary School Standard Curriculum (KSSM) form 1. Based on Table 7, the researcher will focus on three subtopics in the topic of Form 1 Geometry namely Lines & Angles, Polygons and Perimeter & Area which are implemented for 4 weeks of teaching and learning period according to Curriculum and Assessment Standard Document (DSKP) and Annual Teaching Plan (RPT) of Form 1 Mathematics as prescribed by the Ministry of Education Malaysia (MOE).

7 Findings

7.1 The differences between levels of computational thinking for control and treatment group students before and after learning the geometry topic

This section describes the differences in the level of Computational Thinking for control group students (conventional learning) and treatment (learning using Augmented Reality Applications with Computational Thinking) before and after learning geometry. Pre- and post-tests were conducted with 62 students for each group to identify the differences based on matched-samples t-test.

A comparison of pre-tests for the control group and the treatment group in Table 8 shows the null hypothesis H_o1 cannot be rejected ($t = 1.979$, $p > 0.05$). The results of the data analysis based on the t-test are insignificant; there is no difference between control and treatment groups in the levels of Computational Thinking before learning the topic of Geometry. Table 8 shows that the mean score of the pre-test for the two groups of students is not large enough to reject the null hypothesis. The mean score of the pre-test for the control group ($M = 47.19$, $SD = 15.04$) and the mean score for the treatment group was ($M = 42.45$, $SD = 12.76$). The mean score difference is 4.74 points. Meanwhile, the comparison of the post-test for the control group and the treatment group in Table 9 shows the null hypothesis, H_o2 was rejected ($t = —8.698$, $p < 0.05$). The results of data analysis based on the t-test are significant since there is a difference between the level of Computational Thinking for students after learning geometry between both control and treatment groups. Based on Table 9, it was found that the treatment group of students obtained a higher post-test mean score than the mean score of the control students after the intervention was implemented. Students in the control group obtained a mean score

Table 5 Timetable for research on teaching and learning practice

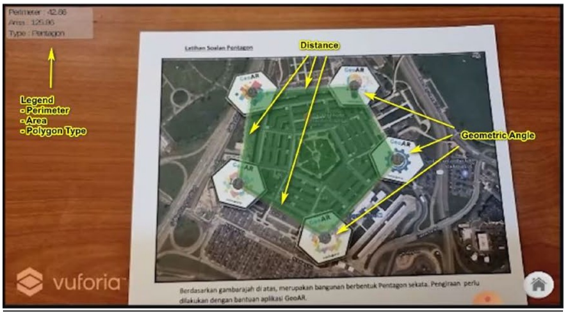
Controlled Group	Week	Treatment Group
Sub Topic 1: Line & Vertex - Conventional Teaching and Learning ● Know, compare and contrast plus explain vertex of the angle for parallel lines, reflect angle, and complete corresponding angle	1	Sub Topic 1: Line & Vertex -The use of Augmented Reality application with Computational thinking ● Virtual content (Augmented Reality) know, compare and contrast plus explain vertex of the angle for parallel lines, reflect angle, and complete corresponding angle
Sub Topic 2: Basic Polygon - Conventional Teaching and Learning ● Explain the relation between number of sides, vertex and vertex of the polygon. Lable vertex of the polygon and give names to polygon ● Know and list Geometrical elements for various types of triangular and square	2	Sub Topic 2: Basic Polygon -The use of Augmented Reality application with Computational thinking ● Virtual content (Augmented Reality) labling and naming, number of sides, vertex and vertex of the polygon ● Virtual content (Augmented Reality) Geometrical elements for various types of triangular and square
Sub Topic 3: perimeter & Space - Conventional Teaching and Learning ● Determine various types of perimeter when long parallel lines is given or needs to be measured ● Estimate various types of space by using any methods	3	Sub Topic 3: perimeter & Space -The use of Augmented Reality application with Computational thinking ● Virtual content (Augmented Reality) determine various types of perimeter when long parallel lines is given or needs to be measured ● Estimate various types of space by using any methods
Sub Topic 4: Problem solving for Combination Geometrical Problem - Conventional Teaching and Learning ● Solve problem for any matters related to triangular and square ● Solve problem of perimeter and triangular space, square space, parallel square, kite, trapezium and combination any types of shape	4	Sub Topic 4: Problem solving for Combination Geometrical Problem -The use of Augmented Reality application with Computational thinking ● Solve problem for any matters related to triangular and square, perimeter and triangular space, square space, parallel square, kite, trapezium and combination any types of shape

Table 6 Samples of user displays while using geoar application in geometry exercise

No.	Picture	Description
1.	Before Scanning with GeoAR Application (Triangle Question Exercise)  During Scanning with GeoAR Application (Triangle Question Exercise) 	Pupil scans GeoAR application at point A, B, and C by using marker and green virtual of triangle form appears. Any movement of the marker at the picture will cause dynamic changes for edge, distance, perimeter and area. Based on the display, pupil solves the geometry problem for the triangle shape.
2.	Before Scanning with GeoAR Application (Pentagon Question Exercise) 	Pupil scans GeoAR application at point A, B, C, D, and E by using marker and a green virtual depiction of the Pentagon form appears. Any

Table 6 (continued)

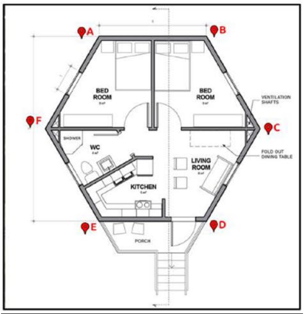
During Scanning with GeoAR Application (Pentagon Question Exercise)



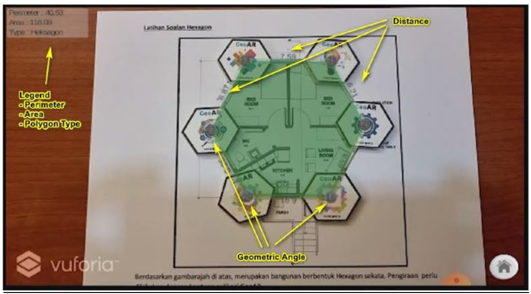
movement of the marker at the picture will cause dynamic changes for edge, distance, perimeter and Area. Based on the display, pupil solves the pentagon shape geometry problem.

3.

Before Scanning with GeoAR Application (Hexagon Question Exercise)



During Scanning with GeoAR Application (Hexagon Question Exercise)



Pupil scans GeoAR application at point A, B, C, D, E, and F by using marker and a green virtual depiction of a hexagon form appears. Any movement of the marker at the picture will cause dynamic changes of edge, distance, perimeter and area. Based on the display, the pupil solves the hexagon shape geometry problem.

Table 7 Augmented reality embedded on the curriculum of geometry

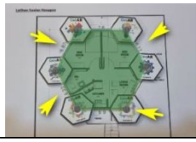
Week	Topic in Curriculum	Learning Standard in Curriculum	Augmented Reality embedded on the the curriculum of Geometry
Week 1	Line & Angle	• Recognize, compare differences and describe the properties of angles on straight lines, reflex angles, and complete rotation angles. • Identify, describe and draw opposite angles and adjacent angles on intersecting lines, including perpendicular lines • Recognize, describe and draw corresponding angles, intersecting angles and deepening angle. • State the relationship between the number of sides, edges and diagonals of polygon. Label the corners of the polygon and name the polygon.	-The use of Augmented Reality application with Computational thinking. • Virtual content (Augmented Reality) to recognise, compare differences and describe the properties of angles on straight lines, reflex angles, and complete rotation angles. 
Week 2	Polygon Base	• Recognise and list nature of Geometry for various triangle patterns. Then, classify triangle according to nature of Geometry. • Elaborate nature of Geometry for various types of four sides. Then, classify four sides according to nature of Geometry. • Solve problem which involves the combination of triangle and four sides.	-The use of Augmented Reality application with Computational thinking. • Virtual content (Augmented Reality) to lable and name, number of sides, edge and polygon diagonal. • Virtual content (Augmented Reality) nature of Geometry for various triangle and square patterns. 
Week 3 Week 4	Perimeter & Area	• Determine various types of perimeter when sides length are given or need to be measured. • Estimate the perimeter of various shapes, then evaluate the accuracy of estimation by comparing the measured value. • Solve problems involving perimeter. • Estimate the area of various shapes using various methods. • Solve problems involving triangles, paralellograms, hovers, trapezoids and combination of these shapes. • Make and confirm conjectures about the combination of perimeter dan area. • Solve problems involving perimeters and area of triangle, rectangles, equal squares, paralellograms, hovers, trapezoids and combination of these shapes.	-The use of Augmented Reality application with Computational thinking. • Virtual content (Augmented Reality) to determine perimeter of various shapes pelbagai bentuk when sides length are given or need to be measured, estimate the area of various shapes by using various methods. 

Table 8 Pre-test computational thinking level analysis

Paired Differences					
Group	Mean	SD	t	df	Sig (2-tailed)
Control	47.19	15.04	1.979	61	.052
Treatment	42.45	12.76			

$n = 62$, students, $\alpha = 0.05$

Table 9 Post-test computational thinking level analysis paired differences

Paired Differences					
Group	Mean	SD	t	df	Sig (2-tailed)
Control	49.35	13.95	-8.698	61	.000
Treatment	67.87	11.96			

$^{*}n = 62$, students, $\alpha = 0.05$

Table 10 Size effects and post hoc power analysis

d	Power	t	*δ*	*n*	Df
1.105	1.00	1.670	8.700	7	61

of (M = 49.35, SD = 13.95) the mean score of the treatment group was (M = 67.87, SD = 11.96). The mean score difference is 18.52 points.

Table 10 shows the effect sizes and the results of the post hoc power analysis. The power was 1.00 (100%) based on total sample (n = 62), effect size (d = 1.105) and alpha (0.05), indicating the probability of rejecting the null hypothesis of this study was 100%. Prior power analysis also illustrates that the proposed sample number seven is sufficient for the effect size value of 1.105 based on alpha (0.05) and power (0.8) values. Therefore, the number of samples in this group (n = 62) exceeds the necessary sample size.

7.2 The differences between levels of visualisation skills for control and treatment group students before and after learning the topic of geometry

This section describes the differences in the level of Visualisation Skills for control group students (conventional learning) and treatment (learning using Augmented Reality Applications with Computational Thinking) before and after learning geometry. Pre-tests and post-tests were conducted with 62 students in each group to identify the differences using a matched-samples t-test.

A comparison of pre-tests for the control group and treatment group in Table 11 shows the Null Hypothesis, H_o3 cannot be rejected ($t = —1.432$, $p > 0.05$). The

Table 11 Pre-test visualisation skills level analysis

Paired Differences					
Group	Mean	SD	t	df	Sig (2-tailed)
Control	60.84	13.31	-1.432	61	.157
Treatment	63.85	12.05			

*$n = 62$, students, $\alpha = 0.05$

results of the data analysis based on t-test are not significant; there is no difference between the level of Visualisation Skills before learning the topic of Geometry between groups of students that is the control group and the treatment group. Based on Table 11, it is found that the mean score of the Pre-test for the two groups of students is not large enough to reject the Null hypothesis (H_o). The mean pre-test score for the control group was (M = 60.84, SD = 13.31) and the mean score for the treatment group was (M = 63.85, SD = 12.05). The mean score difference is 3.01 points. Meanwhile, the comparison of the Post-test for the control group and the treatment group in Table 12 shows the Null Hypothesis, H_o4 is rejected (t =—7.203, $p < 0.05$). The results of the t-Test are significant; there is a difference between the level of Visualisation skills for students after learning the topic of Geometry between both control and treatment groups. As shown in Table 12, the treatment group obtained a higher post-test mean score than the mean score of the control students after the intervention was implemented. Students in the control group obtained a mean score of (M = 57.42, SD = 18.95), and the mean score of the treatment group was (M = 78.23, SD = 12.13). The mean score difference is 20.81 points.

Table 13 shows the results of the effect size and post hoc power analysis. The power is 1.00 (100%) based on total sample (n = 62), effect size (d = 0.915) and alpha (0.05), indicating that the probability of rejecting the Null hypothesis of this study is 100%, which avoids the occurrence of Type I Error i.e., rejecting the correct Null Hypothesis (H_o). The prior power analysis also has shown that the proposed sample number 12 is sufficient for the Size Effect value of 0.915 based on

Table 12 Post-test visualisation skills level analysis

Paired Differences					
Group	Mean	SD	t	df	Sig (2-tailed)
Control	57.42	18.95	-7.203	61	.000
Treatment	78.23	12.13			

*$n = 62$, students, $\alpha = 0.05$

Table 13 Size effect and post hoc power analysis

D	Power	T	δ	*n*	Df
0.915	1.00	2.000	7.205	12	61

Table 14 Pre-test geometry topics achievement level analysis paired differences

Group	Mean	SD	t	df	Sig (2-tailed)
Control	50.94	19.07	-1.857	61	.068
Treatment	56.03	17.73			

*$n = 62$, students, $\alpha = 0.05$

Table 15 Post-test geometry topics achievement level analysis paired differences

Group	Mean	SD	t	df	Sig (2-tailed)
Control	57.42	18.95	-4.473	61	.000
Treatment	71.47	18.57			

*$n = 62$, students, $\alpha = 0.05$

Alpha (0.05) and Power (0.8) values. Therefore, the number of samples in this group (n = 62) has reached a significant level which exceeds the required sample size.

7.3 The differences between geometry topic achievement levels for control and treatment group students before and after learning geometry topics

This section describes the differences in the level of achievement of Geometry Topics for control group students (conventional learning) and treatment (learning using Augmented Reality Applications with Computational Thinking) before and after learning Geometry topics. Pre-test and Post-test were conducted on 62 students for each group to identify the differences based on Matched-samples t-test.

A comparison of pre-tests for the control group and the treatment group in Table 14 shows the Null Hypothesis, H_o5 cannot be rejected ($t = -1.857$, $p > 0.05$). The results of data analysis based on the t-test is not significant since there is no difference between groups in the level of achievement of Geometry Topics before learning geometry. Based on Table 14, it is found that the mean score of the pre-test for the two groups of students is not large enough to reject the Null hypothesis (H_o). The control group had a pre-test mean score of (M = 50.94, SD = 19.07), and the mean score for the treatment group was (M = 56.03, SD = 17.73). The mean score difference is 5.09 points. Meanwhile, the comparison of the Post-test for the control group and the treatment group in Table 15 shows the null hypothesis, H_o6 is rejected ($t = -4.473$, $p < 0.05$). The results of the t-test are significant, indicating that there is a difference between the two groups in the level of achievement of Geometry topic after learning using Augmented Reality Application with Computational thinking. The treatment group students obtained a higher post-test mean score than the mean score of the control students after the intervention was implemented. The control group obtained a mean score of (M = 57.42, SD = 18.95), and the mean score of the treatment group was (M = 71.47, SD = 18.57). The mean score difference is 14.05 points.

Table 16 Size effects and post power hoc analysis

d	Power	t	δ	n	Df
0.568	1.00	2.000	4.47	27	61

Table 16 shows the results of the effect size and post hoc power analysis. The power is 1.00 (100%) based on total sample (n = 62), effect size (d = 0.568) and alpha (0.05), indicating that the probability of rejecting the null hypothesis of this study is 100%, avoiding the occurrence of Type I Error i.e., rejecting the correct Null Hypothesis(H_o). The prior power analysis conducted also showed that the proposed sample number 27 was sufficient for the effect size value of 0.568 based on alpha (0.05) and power (0.8) values. Therefore, the number of samples in this study (n = 62) exceeds the required sample size.

7.4 The differences in students' existing knowledge of computational thinking, visualisation skills and achievement in geometry topics between control groups and treatment groups

After obtaining an overview of the overall effectiveness of the intervention, the researchers conducted a MANCOVA to see if there are differences in students' existing knowledge of Computational Thinking, Visualisation Skills and Achievement in Geometry Topics between the control group and the treatment group. Prior to the MANCOVA, the covariance variance homogeneity matrix test was first determined by using the Box's M test and Levene's test. Box's M test findings show that there is no difference in variance and covariance between the dependent variable and the independent variable (F = 1.617, p = 0.138) (p > 0.05). This means that the variance and covariance of homogenous dependent variables across independent variables The Levene's test, on the other hand, was to determine the uniformity of variance for the control group and the treatment group, i.e., the scores for the dimensions of Computational Thinking, Visualisation Skills and Achievement of Geometric Topics of the two groups were not different. Table 17 shows the Levene's test for the three dependent variables namely, Computational Thinking, Visualisation Skills and Achievement of Geometry Topics.

The findings of the Levene's test show that the variance and covariance for all variables are similar. In terms of observed power, this shows that all dependent variables are good (p > 0.05) and this gives the impression that all variables have met the assumptions to enable the MANCOVA to be conducted.

Table 17 Levene's tests based on computational thinking, visualisation skills and achievement of geometry topics

Test	F-value	dk 1	dk 2	p
Computational Thinking	3.847	1	122	0.052
Visualisation Skills Geometry Topics' Achievement	1.586	1	122	0.455
Geometry Topics' Achievement	0.430	1	122	0.716

Table 18 Multivariate testing

Effect		Value	F	Hypothesis dk	Error dk	Sig
Existing Knowledge	Pillai's Trace	.059	2.475^{b}	3	119	.065
Teaching Method	Pillai's Trace	.468	34.882^{b}	3	119	.000

The test results of the *Multivariate Pillai`s Trace* in Table 18 show that there is a significant effect of independent variables (teaching methods) [F(3, 119) = 34.88, p < 0.05]. However, there was no effect of the control variables (Existing Knowledge) on the dependent variables [F(3, 119) = 2.48, p > 0.05]. Based on these results, we reject the null hypothesis and concludes that overall, teaching methods using Augmented Reality applications with Computational Thinking are factors in the improvement of Computational Thinking scores, Visualisation skills and Geometry Topics' Achievement.

The results in Table 19 show that there is a significant effect of teaching methods using Augmented Reality application with Computational Thinking on the improvement of achievement of the three dependent variables namely, for Computational Thinking, Visualisation Skills and achievement of Geometric Topics, namely, Computational Thinking [F(1, 121) = 62.19, p < 0.05], Visualisation Skills [F(1, 121) = 47.76, p < 0.05] and Geometry Topic's achievement [F(1, 121) = 16.92, p < 0.05]. R2 values indicate the independent variable (Teaching Methods using Augmented Reality application with Computational Thinking) contributed 35.3% change in Computational Thinking, and as much as 28.5% change in the achievement of Geometry Topic and a 15.7% change in Visualisation Skills.

8 Discussion

The results of the study have shown that the intervention was successfully implemented. With regard to Computational Thinking, it was found that the treatment group obtained a higher post-test mean compared to the mean score of the control group after the intervention was implemented. The results also have shown

Table 19 Between-subjects effects test

		Type III Sum of Squares	dk	Mean Square	F	Sig
Existing Knowledge	Computational Thinking	10,390.680	1	10,390.680	62.189	.000
	Visualisation Skill	6591.990	1	6591.990	47.757	.000
	Geometry Topics' Achievement	5783.804	1	5783.804	16.918	.043

a. R Squared = .353 (Adjusted R Squared = .342)

b. R Squared = .285 (Adjusted R Squared = .273)

c. R Squared = .157 (Adjusted R Squared = .143) that the effectiveness of the intervention was not influenced by students existing knowledge. The results show that there is a significant effect of teaching methods using Augmented Reality application with Computational Thinking on the improvement of achievement of the three dependent variables namely, Computational Thinking, Visualisation Skills and achievement of Geometric Topics. This study is an extension to several previous studies that used Computational thinking in the problem-solving process in learning (Anna et al., 2017; Barcelos et al., 2018; Batı, 2018; Gong et al., 2020). A study by Gong et al. (2020) has shown that learning strategies using Computational thinking are among the factors that can influence student learning. Research findings have also shown an increase in Computational thinking scores in the treatment group which is in line with the findings of the study by (Gong et al., 2020; F. González et al., 2018; Sırakaya et al., 2020; Wong & Jiang, 2019). What differentiates is that, the study of Gong et al. (2020) has used the elements of Computational thinking based on Korkmaz et al. (2017) which involve five dimensional constructs namely creativity, collaboration, algorithmic thinking, critical thinking and problem solving. In addition, Selby and Woollard (2013) have stated that Computational thinking is an approach focusing on problem solving, combining thought processes that uses Abstraction, Decomposition, Algorithm design, Evaluation and Generalization.

Harangus and Kátai (2020) have explained that Computational thinking can be effective if students' cognitive abilities are considered and these abilities will be developed in different learning contexts. Even Román-gonzález et al., provided new evidences that the nature of Computational thinking is associated to cognitive abilities such as Visual Spatial skills, reasoning ability and problem-solving ability. This study clearly demonstrates that the elements of Computational thinking that are implemented can improve the learning of Geometry topics and it backs up the findings of Echeverría et al. (2019) who found that Computational thinking strategies can improve the learning of Geometry topics. This study clearly shows that the implementation of Computational thinking element can enhance Geometry topic learning and it is proven by the study conducted by Echeverría et al. (2019). In fact, the study also shows Computational thinking strategy can enhance Geometry topic learning. Besides, the study done by Baiduri et al. (2020); Baranová and Katreničová (2018), have proven that Geometry topic has a connection with Visualisation Spatial skill. This study is trying to foresee the new perspective for solving problem of the geometry topic by implementing Computational thinking. The study by Sırakaya et al. (2020) also has correlation especially in terms of the integration in the Computational Thinking focusing in STEM by comparing the research of Mathematics subject and focusing on Geometry topic. This study also emphasizes on Computational Thinking framework which is used as one of the conceptual framework components.

Problem-solving skills and the use of technology are extremely important. According to Hani and Asarani (2020), Computational Thinking is a thought process to formulate and find solutions to problems by using technological tools or methods that can be implemented. However, Computational Thinking approaches in schools are still quite limited (Chalmers, 2018), it is therefore of great interest to the researchers to see the potential of this approach in the problem-solving learning process. For Visualisation Skills, there were also positive results for the treatment group, who obtained a higher post-test mean score than the control group after the intervention was implemented. The results are in line with Hanafi et al. (2017), who stated that spatial visualisation skills play a significant role in the development of higher order thinking for the students' study of geometry.

Furthermore, the findings of analysis of student achievement data in post-test for treatment group as shown in Table 12 show that students' Visualisation skills improved after learning using Augmented Reality application with Computational thinking as compared to learning using conventional methods for the Geometry topic. This is in line with Gavita (2016) study, which has found that students gain greatly from applying visualisation skills when answering Mathematical problem-solving problems. Mathematics subjects with Visualisation skills have an important correlation, according to Mix et al. (2016) who have reported that Visual Spatial and Mathematical skills are two highly correlated domain factors and show a strong relationship between Visual Spatial and Mathematical skills. Students with good Visual Spatial skills have shown better performance in Mathematics and also pursued longer and more successful careers in STEM (Geary et al., 2000; Laski et al., 2013). In addition, the findings of the study have also compared the achievement of students in the post-test for the control group and the treatment group which showed that the Visualisation skills for the achievement of the treatment group is higher than the control group. These findings further support the opinion that Spatial Visualisation capabilities can be developed through the use of various learning media (Erbas & Yenmez, 2011; Susilawati et al., 2017). In addition to that, after using the Augmented Reality application, the achievement of Visualisation skills for the treatment group has improved and showed a positive impact in learning the topic of Geometry. This is in line with the study of Yoon et al. (2017) which has shown that Augmented Reality improves the ability to visualize hidden details and information to aid the learning process.

The results of analysis of student achievement data in pre and post-test for treatment group as shown in Table 14 and 15 show that student achievement of Geometry topic improved after learning using Augmented Reality application with Computational thinking as compared to learning using conventional method in Geometry topic. This is in line with studies by (Erbas & Yenmez, 2011; González, 2015; Khor et al., 2017) have proven that students get many positive benefits when using technology in the topic of Geometry. Specifically, in this study using Augmented Reality technology in learning process is also consistent with many previous studies showing improvement of academic achievement after use of Augmented Reality technology in learning process (Akçayır & Akçayır, 2017; Kaya & Bicen, 2019). Conventional learning of Geometry topics based on two-dimensional drawing methods is not very successful when learning three-dimensional Geometry objects (Battista, 2003; Olkun, 2004). Drawings that represent 3D displays are usually seen in two-dimensional form in the learning process and are often unable to help students understand the concept of representation and the nature of 3D components. The properties of components such as side length, number of sides, relationship between similar components such as equal sides, angles and sides that will form the structure of the object (Battista, 2007). Given the conventional learning of the concept of three-dimensional Geometry, students may not be able to compare the volumes of two cylinders by referring only to 2D drawings and formulas. This example emphasizes the need for Spatial Visualisation skills which suggests that learning the topic of Geometry should use appropriate methods in addition to memorization techniques (Battista, 2007). Many studies have portrayed that the use of software in Geometry topics can help improve the learning achievement of Geometry topics such as studies by (Baranová & Katreničová, 2018; Mavani et al., 2018) who have used GeoGebra software and Ibáñez et al. (2020) together with Augmented Reality application.

In addition, achievement in geometry topics demonstrated that the treatment group obtained a higher post-test mean score than the mean score of the control group after the intervention was implemented. The results show that there is a positive effect of teaching methods using Augmented Reality applications with Computational Thinking for students. Based on Table 9, there is an increase in the level of Computational thinking for the treatment group indicating that there is a need to implement this problem-solving strategy in the Geometry topic curriculum. This idea is also in line with Alex and Mammen (2018) opinion which has suggested the changes for Geometry topic curriculum that emphasizes on the model on how students can understand Geometry thinking. In addition, Shute et al. (2017) has explained that there is still no existing curriculum to build the foundation of Computational thinking for students' understanding as in the subject of Mathematics. A framework or model is needed to help highlight Computational thinking in current classroom practice, as many problems in the current curriculum can be addressed using Computational thinking. Meanwhile, Hill (1998) has explained the importance of incorporating problem solving and design processes as part of the curriculum. Another finding from Hill (1998) study has indicated that when students are allowed to learn through technology in problem-solving as an exploration will cause creativity to be formed and enhance students' learning. Moreover, based on Table 12, there is an improvement for Visualisation skills for the treatment group indicating the importance of the application of Visualisation skills in the Geometry topic curriculum. Sinclair et al. (2017) has an idea there is an improvement of the concentration for Geometry learning curriculum which emphasizes on visual spatial reasoning and digital tool usage. The effectiveness of specific digital tool has influenced the study of the topic including Geometry curriculum. Besides, there is an issue related to digital technology role in the process of developing students' spatial ability of 3D Geometry for designing Geometry teaching and learning with the availability of technology (Liang & Baccaglini-Frank, 2016).

This gives the impression that learning using Augmented Reality applications combined with Computational Thinking provides an advantage to the treatment students' group in terms of solving geometry problems, as well as improves their Visualisation Skills during the Geometry problem-solving process. This is in comparison to the control group's lower scores on the Geometry Achievement Test, where the group has used conventional learning methods. There are also studies Lin et al. (2021) that show Augmented Reality application does not directly affect student's Computational thinking in the coding context. Furthermore, in the coding context, student is using computer software programming for coding exercise process. It is agreed that Augmented Reality applications can assist student during the process of understanding problem (Lin et al., 2021). This situation clearly shows that Computational thinking concepts can help students understand and solve geometry problems in the research context. In conclusion, the Computational Thinking approach in topics of solving Geometry problems with the help of Augmented Reality technology gives many advantages to students by developing their understanding of problem-solving. The use of technology with Computational Thinking in problem-solving corresponds directly to the statement by Gibson (2012) which suggests that Computational Thinking skills should be enhanced from the aspect of teaching aids for students in their learning process.

The implication of "the effectiveness of the intervention in more depth on Computational Thinking, Visualisation Skills and students' achievements on Geometry Topic after controlling for existing knowledge factors." has been performed to determine whether there are significant differences in Computational thinking, Visualisation Skills and Geometry topic achievement between the control group and the treatment group by controlling for covariates (control variables). Furthermore, the implications of the study have also shown that the use of Augmented Reality applications with the implementation of Computational thinking in Geometry topic learning is a major factor in improving achievement in Geometry topic, Visualisation skills level and Computational thinking level of students without being influenced by students' existing knowledge. This can be identified in Table 18 which shows that there is a significant effect of independent variables (teaching methods) and there is no effect of the control variables (existing knowledge) on the dependent. Therefore, the implications of this study clearly show that learning using Augmented Reality applications which is a technology in line with the Industrial Revolution 4.0 is proven to be able to attract students and even allow them to learn more easily and effectively. In fact, this study will also have implications for the secondary school Mathematics curriculum by using Computational thinking in problem solving, and student achievement in Geometry topic can be improved. Learning strategies using Augmented Reality application with the implementation of Computational thinking in the topic of Geometry are seen to have a positive impact in increasing students' interest and understanding of the topic of Geometry.

In addition, the implications in this research show that the use of Augmented Reality application with the implementation of Computational thinking in learning Geometry topic is a major factor in improving students' understanding and achievement of problem solving in Geometry topic and students' existing knowledge factor can be deducted based on empirical data evidence with reference to Table 18. Although previous studies have also looked at the contribution of each theory separately and demonstrated the ability to improve students' mastery and understanding, the advantages of this study have proven that the integration of the elements of Augmented Reality System (S. Liang, 2016), the principal of Visualisation ability (Gutiérrez, 1996) and elements of Computational thinking (Angeli et al., 2016) have successfully improved students' mastery and understanding of the topic of Geometry as well as forming a conceptual framework that can be used as a reference and guide for educators and other researchers in the future. Even with the creation of Augmented Reality applications with the implementation of Computational thinking has given a new contribution to the field of educational technology. This technology has been developed not only as a teaching aid but also shows that it can be integrated as an approach to problem solving in learning as per stated in this study. This study has proven that a combination that produces a conceptual framework such as, Augmented Reality system elements, Visualisation ability principles and Computational thinking elements can be integrated and intertwined in making a learning process more meaningful and effective especially in the topic of Geometry. Furthermore, this Augmented Reality application with Computational thinking can also contribute to the policy of the Ministry of Education Malaysia (MOE) through the Malaysian Education Blueprint (PPPM) 2013–2025 (Preschool to post-secondary Education) in the 7th Shift which is to utilize the use of ICT to improve the quality of ICT for learning in Malaysia as well as maximizing the use of expanding access to high quality teaching and learning.

9 Conclusion

This study shows that there are significant differences in Computational Thinking, Visualisation Skills, and achievement of Geometric Topics of students before and after being taught using the Augmented Reality application learning approach with Computational Thinking. The results show that there are significant differences in students' Computational Thinking, Visualisation Skills, and achievement of Geometry Topics after being taught using the Augmented Reality application learning approach with Computational Thinking versus conventional learning. The study has given contribution and novelty which is Augmented Reality application with the implementation of Computational Thinking in the Geometry learning topic has successfully helped enhancing students understanding and achievement for solving problem of the Geometry topic. Even the previous studies have identified the contribution of each theory is individually and they have shown that the ability to enhance students ability and understanding. In this regard, it has proven that the integration of Augmented Reality System (Liang, 2016), Visualisation ability principle (Gutiérrez, 1996) and Computational Thinking element (Angeli et al., 2016) successfully enhances level of mastery and understanding for students towards Geometry topic which can be used as reference and guidelines for educators and researchers. In fact, the outcome of Augmented Reality application with the implementation of Computational Thinking has contributed to the latest and advance technology for educational field. The technology has been developed, not only for teaching aid yet it has proven that the approach can be integrated for problem-solving in learning. It is clearly shown in this study by which the use of Computational Thinking has given great influence in Geometry topic. As a conclusion, the findings show that students in the treatment group are better at Computational Thinking, Visualisation Skills, and achievement of Geometry Topics compared to the control group. In addition, the results show that overall, teaching methods using Augmented Reality applications with Computational Thinking are factors in the improvement of Computational

Thinking scores, Visualisation Skills and achievement of Geometric Topics that is no effect of existing knowledge students influence the results of these three dependent variables.

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Declarations

Conflict of interest None

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