International Journal of Instruction
e-ISSN: 1308-1470 ● www.e-iji.net

July 2023 ● Vol.16, No.3
p-ISSN: 1694-609X
pp. 1033-1054

Article submission code: 20220912041029

Received: 12/09/2022
Revision: 21/02/2023

Accepted: 18/03/2023
OnlineFirst: 30/05/2023

Augmented Reality: The Improvement of Computational Thinking Based on Students' Initial Mathematical Ability

Lilis Marina Angraini
Universitas Islam Riau, Indonesia, *lilismarina@edu.uir.ac.id*

Fitriana Yolanda
Universitas Islam Riau, Indonesia, *fitrianayolanda@edu.uir.ac.id*

Ilham Muhammad
Universitas Pendidikan Indonesia, Indonesia, *ilhammuhammad@upi.edu*

This study's impetus comes from two factors: students' poor computational thinking (CT) skills in mathematics and the rapid development of information technology in the digital era. Through the use of Augmented Reality (AR)-based educational content powered by Unity 3D, which can be used for both online and offline learning based on Initial Mathematical Ability (IMA), this research explicitly intended to increase students' mathematical computational thinking ability. Augmented reality is the use of three-dimensional virtual objects that are displayed in real time onto a real environment. Students' initial mathematical proficiency, where each student has a distinct learning style, is one of the defining variables in the success of mathematics learning. In this case, students' initial mathematical ability is ability that students possess prior to participating in the learning that will be provided. This study focuses on assessing the fundamental level of mathematical skills that determine a student's readiness to learn under the guidance of a teacher. A total of 30 students were randomly selected from each seventh-grade class at a state junior high school in Pekanbaru to partake in this quasi-experimental study throughout the academic year 2022-2023. The subject matter of this study was flat shapes, particularly triangles and quadrilaterals. The methods employed for data collection included two approaches: (1) administering a test to assess mathematical computational thinking ability and (2) conducting interviews. The interview and documentation data were analyzed in a descriptive manner, while statistical tests were employed to analyze the results of the test. The results indicated that utilizing augmented reality media with Unity 3D to enhance students' mathematical computational thinking ability yielded better outcomes compared to traditional learning methods, particularly for students with lower initial mathematical ability levels.

Keywords: learning media, augmented reality, computational thinking, mathematical ability, initial mathematical ability

Citation: Angraini, L. M., Yolanda, F., & Muhammad, I. (2023). Augmented reality: The improvement of computational thinking based on students' initial mathematical ability. *International Journal of Instruction*, *16*(3), 1033-1054. https://doi.org/10.29333/iji.2023.16355a

INTRODUCTION

Changes in world development marked by the development of information technology require the education world to be able to design a curriculum that can grow the ability of students in accordance with the development of technology and information. One of the abilities that support the development of technology and information is the computational thinking ability (Malik, 2018).

Computational thinking refers to a cognitive approach characterized by the ability to express problems and their corresponding solutions in a manner that enables efficient functioning of computers, individuals, or other technological systems (Wing, 2017; Doleck et al., 2017; Durak & Saritepeci, 2018; Lee et al., 2014). Computational Thinking involves a fusion of cognitive skills wherein an instructor must recognize recurring patterns, tackle intricate problems by breaking them down into smaller steps, devise a set of instructions to achieve solutions, and generate data representations through simulation (Mauliani, 2020; Yadav et al., 2017; Humpreys, 2015; Kalelioglu et al., 2016). Computational Thinking can also train the brain to get used to thinking logically, structured, and creatively (Mufidah, 2018; Korkmaz et al., 2015; McNicholl, 2018; Yadav et al., 2014; Román-González et al., 2017).

Mathematics is one of the disciplines that need computational thinking abilities. Mathematics is a science that can only be understood by reasoning, and it is frequently referred to as a tool for logical, imaginative, and critical thinking. Mathematics holds significant importance as an academic discipline, serving as a valuable indicator of students' learning proficiency and their logical thinking capabilities.

Consequently, the acquisition of Computational Thinking skills becomes crucial for students, as it enables them to effectively organize their approach towards tackling intricate problems (Alfina, 2017; Cansu & Cansu, 2019; Fajri et al., 2019; Putra et al., 2019; Syarifuddin et al., 2019). In addition, according to the world economic forum, Computational Thinking is also an important skill needed in the future because by mastering this ability, students will be better prepared to survive and compete in the future. There are two major steps in Computational Thinking, namely the logical thinking process followed by decision-making and problem-solving (Yang et al., 2018).

Computational thinking abilities can be improved or developed through the application of AR media (Fukuda, 2019; Mustaqim, 2016; Prasetyo & Sutopo, 2018). The application of AR media can help achieve learning objectives (Fitri Ayu et al., 2022; Mustaqim & Nanang, 2017; Sidik & Vivivanti, 2021). The utilization of augmented reality (AR) technology in education proves beneficial in imparting knowledge, skills, and attitudes while also effectively capturing students' attention and fostering their interest. This, in turn, leads to more focused and regulated learning experiences.

The use of technology in teaching and learning activities is very beneficial. Today, technological advancement may be seen in many facets of daily life. Without altering the material's content, educators must create engaging learning materials. Augmented reality has emerged as a viable alternative to conventional educational resources, fostering and enhancing students' creativity. Through the utilization of augmented reality learning materials, students can experience a nurturing environment that promotes the development of their imaginative capabilities (Nurrisma et al., 2021).

Mahendra (2016), Muntahanah et al. (2017), Nurhasanah & Putri (2020), Rawis et al. (2018), Rusnandi et al. (2016) Augmented reality is a technology that combines computer-generated virtual objects with the real world in real time. It involves integrating two-dimensional or three-dimensional virtual elements into the physical environment. By doing so, augmented reality enhances the real world by adding virtual elements that appear to coexist with reality. This technology allows users to experience virtual objects as if they were truly present in the physical world, leading to engaging and immersive interactions. To ensure effective implementation of AR technology and improve the efficiency of digital image processing, certain conditions must be fulfilled.

Studies related to the importance of CT ability have been carried out previously (Cahdriyana & Richardo, 2020; Kadarwati et al., 2020; Lestari & Annizar, 2020; Tresnawati et al., 2020; Zahid, 2020). Other researchers have focused on identifying the effectiveness of CT abilities in increasing students' creativity, identifying the relationship between CT abilities and critical thinking, identifying the establishment of CT capabilities through the Bebras challenge, and identifying CT abilities in mathematics learning. In the meantime, the other studies related to the using of augmented reality media in learning have been carried out as well (Idhami et al., 2020; Mustaqim, 2016; Mustaqim & Nanang, 2017; Nugroho & Pramono, 2017; Nuraisa et al., 2019; Rosali & Suryadi, 2021; Saputri & Sibarani, 2020; Setyawan, 2019; Sidik & Vivivanti, 2021; Suciliyana & Rahman, 2020; Yuntawati et al., 2021). In this case, the researchers have focused on identifying the application of AR in various aspects, including in the introduction of building objects, as a media for children's health, in learning mathematics, as a learning medium, in computer network installations, as a science learning media, and for interior design.

Learning ability encompasses various aspects, including the approach to learning, existing knowledge, areas of ignorance, and the assessment of future learning goals. Basically, the initial ability is the cognitive capacity that a person acquires in previous learning to the new learning process. The initial proficiency of students plays a crucial role in the teaching and learning process, particularly in preparing them to grasp more advanced concepts (Gais & Afriansyah, 2018; Hanafi et al., 2019; Purnamasari & Setiawan, 2019; Supianti et al., 2021; Zulkarnain, 2019). When students possess a higher level of initial ability, they tend to grasp and comprehend the topics presented by their teachers more effortlessly, leading to improved learning outcomes (Angraini, Kusumah & Dahlan, 2019). In light of students' initial mathematical ability, this study sought to determine whether students' mathematical computational thinking skills had improved through learning processes using augmented reality media with Unity 3D.

Literature Review

Computational Thinking is indispensable in mathematics (Kawuri et al., 2019; Yasin, 2020). The acquisition of mathematical skills, which is intricately connected to problem-solving, necessitates students to possess a capacity for computational thinking. CT is basically a student's thinking activity in understanding the context of the problem, where the students will further reason up to the abstraction stage and end up in systematic problem solving (Cahdriyana & Richardo, 2020; Zydney et al., 2020).

Computational Thinking enables students to enhance their decision-making abilities and facilitate the resolution of mathematical problems with greater ease (Lee et al., 2014). Therefore, several developed countries began to update the education curriculum in schools in 2014 to introduce and train students' computational thinking ability from an early age (Città et al., 2019). This was carried out based on the belief that computational thinking trains the brain to think logically, **in a structured way**, and systematically (Maharani, 2020).

Computational Thinking is an ability that supports the problem-solving process in learning mathematics. Mathematics and computational thinking are mutually supportive, with the use of computational thinking enhancing the learning of mathematics and science as well as the application of mathematical and scientific contexts enhancing computational thinking ability (Sukamto et al., 2019).

Computational Thinking in mathematics includes: decomposition, patterns and generalizations, abstractions, and algorithms. Decomposition is an attempt to break problem into several parts and solve them one by one. Generalizations and patterns are attempts to recognize regularity or character similarities and then use them as a basis for solving problems. Abstraction is an attempt to translate the problem into a mathematical problem. Meanwhile, the algorithm is in the form of the use of coherent steps in solving problems.

The transmission of messages or materials from the message-giver (teacher) to the message-recipient is known as the learning process (student). Encoding is the process of transforming messages or materials into symbols for verbal and nonverbal communication. Meanwhile, decoding is the interpretation of communication symbols by students. Depending on the message or material, it may or may not be effective in delivery. Noise or a barrier in this communication process is failure. Teachers need educational media to present content during a learning process (Estheriani & Muhid, 2020; Yusnita et al., 2022).

To establish a student-centered learning environment, it is crucial to employ learning resources that effectively inspire students to engage in autonomous learning. This necessitates the utilization of technology as a fundamental component for creating impactful educational materials. Virtual technology, which has emerged as a result of the fourth industrial revolution, represents one such technological innovation. This was chosen because information can be provided about real objects with accuracy thanks to virtual technology. The use of augmented reality is a type of virtual technology (Arifitama, 2017; Hu Tianyu et al., 2017; Fan & Liang, 2012; Zhong et al., 2015).

According to Purnomo & Haryanto (2012), in the field of multimedia and image processing, augmented reality is a development and invention that is currently under development. With the help of this technology, an object that was previously unreal might appear to merge with its surroundings and become genuine. A real-world environment is combined with 2- and 3-dimensional digital objects using augmented reality technology, which then projects the virtual objects in real-time (Rachmanto & Noval, 2018; Haryanto et al., 2018; Zarzuela et al., 2013; Lee & Choi, 2014; Norouzi et al., 2019).

A technology known as "augmented reality" uses two- or three-dimensional virtual objects to be combined with real-world surroundings and then projected in real time. Unity 3D is the creation of moving images in 3-dimensional digital space (Sural, 2018; Wahtu et al., 2020). This was done by creating image frames that simulate movement, filmed with a virtual camera, and the output was in the form of rendered or real-time video, so that learning mathematics was more enjoyable. To run the augmented reality media, there were several steps that students must take. The first step is that students opened the augmented reality media that has been distributed, then students pressed the "start" button to go to the main menu page. The second step is the students could immediately open the material menu by pressing the "material" button and the evaluation menu by pressing the "evaluation" button. In the third step, the Android will automatically open the camera feature, then point the camera at the target images (triangles and quadrilaterals) that have been given. In the fourth step, when a plane view appears, the user can enlarge or reduce objects and rotate objects with existing buttons. In the last step, after students have finished using augmented reality media, users can exit the media by pressing the "exit" button on the top right.

Mahendra (2016), Muntahanah et al. (2017), Nurhasanah & Putri (2020), Rawis et al. (2018), Rusnandi et al. (2016) further stated that augmented reality is a technology that projects virtual things in real time while integrating two-dimensional or three-dimensional virtual objects into a real world. Furthermore, Ananda et al. (2015), Efendi (2020), Partiwi (2019), and Rosa et al. (2019) The three fundamental principles of augmented reality can be summarized as follows: Firstly, it combines the real and virtual realms, bringing them together seamlessly. Secondly, it functions in real time, allowing for interactive experiences. Lastly, it incorporates three-dimensional elements, or virtual objects, into the actual environment, enhancing the user's perception. There are presently many uses for augmented reality systems, including in entertainment, education, science, engineering, manufacturing, and other areas.

METHOD

This research employed an experimental approach to enhance students' computational thinking skills by utilizing **augmented reality (AR) technology**, taking into account their initial mathematical abilities. The study design adopted a quasi-experimental method due to the school's restriction on individual randomization, leading to non-random selection of students as participants. Therefore, the researcher conducted randomized classes, where both classes were taught by the same teacher and had the same initial mathematical ability as well.

This study took place in a junior high school located in Pekanbaru. Specifically, it focused on students in the seventh grade during the academic year 2021/2022. The research explored the topic of flat shapes, with a specific focus on triangles and quadrilaterals. 30 students from two classes the experimental class and the control class made up the study's subjects. The subjects in this study were relatively small because the number of students in each class was only around 18 people. However, during the learning process, some of them were affected by Covid, so that only 15 people routinely took part in offline learning from the start to the end of each class. Although the subject of this study was relatively small, according to (Borg and Gall, 2007) specifically for research simple experiment with tight control research success can be achieved by using a sample of 15-30 respondents per group.

The research subjects in each group were 12-13 years old. Both groups were taught by the same teacher with different treatment. In this scenario, the experimental group was exposed to a learning process that involved the utilization of AR-based learning media through the platform of Unity 3D. On the other hand, the control group experienced a learning process where teaching materials were provided in the form of Student Worksheets. Each learning media used aimed to improve students' computational thinking ability and arranged based on indicators that measure computational thinking ability, namely: decomposition, patterns and generalizations, abstractions, and algorithms.

This research was carried out for 6 meetings (almost 1 month). Before applying the learning media to each group, the researcher gave a test to find out the initial mathematical abilities possessed by each group. Furthermore, after the 6th meeting, the researcher gave a final test to see the improvement occurred in each learning group. At each meeting, each group studied the same material, namely about flat shapes (triangles and quadrilaterals), where each group was taught by the same teacher, the same amount of learning time, and learning media that emphasized learning to improve computational thinking ability.

Furthermore, the instruments used in this research were (1) a computational thinking ability test and (2) interviews. The test consisted of 5 questions, in which each question had a maximum of 20 points. The test results for each student were calculated based on the answer keys that have been prepared, then the researcher clarified students' answers through interviews to ensure their computational thinking ability. Students who were interviewed were only representatives from each category of students' initial mathematical abilities. The following is one of the 5 questions on the student's computational thinking ability test.

Trisna drew right triangles on his playing page. After that Trisna recorded the lengths of the sides of the right triangles, then calculated their circumferences as follows:

Triangle	Side Length (cm)	Circumference (cm)
1	3, 4, 5	12
2	12, 16, 20	48
3	27, 36, 45	108
4	48, 64, 80	202
5	75, 100, 125	300
…	…	…

Based on the data above, Trisna predicted that the 20th triangle will have a circumference of 48 m.

a. Are the notes made by Trisna definitely true, or maybe they are right, or lack data, or maybe they are wrong, or are they definitely wrong? Explain.

b. Find the pattern of the side lengths of the right triangles above and generalize conclusions about the circumferences of the right triangles.

The computational thinking ability test instrument was first validated by experts. In this case, the validators were 2 mathematics education lecturers at a university in Pekanbaru, Indonesia. The test outcomes were assessed using the 2-way Anova analysis. Before conducting the 2-way Anova test, the data underwent prerequisite tests to verify if they satisfied the assumptions of normality and homogeneity. The normality assumption was examined using the Kolmogorov-Smirnov test, while the homogeneity assumption was assessed using the Levene test. If the data did not meet the normality assumption, the analysis was performed using a non-parametric test called the Adjusted Rank Transformation Test.

This research aimed to examine how testing the initial mathematical skills could impact the assessment of students' computational thinking abilities. Good thinking skills are often correlated with strong mathematics skills, and the reverse is also true. weak math skills frequently indicate weak thinking skills as well. Thus, this study will also look at students' initial mathematical ability as one of the determining factors in differentiating students' increased computational thinking ability through the application of AR media with Unity 3D. The categorization of students' initial mathematical ability was further divided into three groups, namely high, medium and low. This categorization is explained in the table below:

Table 1
The category of students' initial mathematical abilities

Score	Category
$X < 30\%$	Low
$30\% \leq X < 70\%$	Medium
$X \geq 70\%$	High

The purpose of this research was to examine, explain, and compare the progress of students in developing their mathematical computational thinking abilities when using augmented reality media with Unity 3D versus those who received traditional instruction. The study took into account the initial differences in students' mathematical abilities by categorizing them as high, medium, or low. Before conducting the study, a pre-test was administered to assess the students' baseline math skills. The results of the pre-test were then used to group the students into the high, medium, and low categories based on their initial abilities. Here is the breakdown of the research sample distribution.

Table 2
The data distribution of research samples

IMA	Control	Experiment (AR)	Amount
High	5	5	10
Medium	5	5	10
Low	5	5	10
Total	15	15	30

Description: Experiment = Augmented Reality.
Control = Conventional Learning.

Statistical evaluation of test findings uses SPSS 26.0 software, which includes two-way Anova, t-tests, descriptive statistics, and the Kolmogorov-Smirnov and Levene homogeneity tests. The data's normality and variance homogeneity were both confirmed before doing any statistical tests, respectively.

FINDINGS AND DISCUSSION

Before this research was conducted, initial mathematic ability data were gathered and analyzed to ascertain students' beginning math ability. The foundational knowledge of mathematics was derived from the prior subject's mathematical value. The results were then divided into groups according to the categories of high, medium, and low initial ability. The data was analyzed in a descriptive manner to obtain key statistics such as the average, variability, lowest value, and highest value, with the aim of gaining a broad understanding of the initial mathematical skills of the students. A summary of the results of the descriptive analysis of student data on their first mathematical proficiency, considering their previous learning achievements, is presented in the table 3:

Table 3
The data description of students' initial mathematical ability

Descriptive statistics	Control	Experiment (AR)
N	15	15
Mean	81.52	80.45
Sd	6.64	6.12
Max	98	100
Min	64	65

According to the table provided, the control class's initial mathematical aptitude is described in a more accurate manner compared to that of the experimental class. Despite the lack of significant difference, the researchers selected students with an average score of 80.45 for the experimental class. Their intention was to surpass the average performance of the traditional instruction group, which is the control class.

Furthermore, before conducting the t-test to compare the initial mathematical ability between the two learning groups, the researchers performed tests to assess data normality and homogeneity of variance. In this case, the Kolmogorov-Smirnov test was employed to determine whether the data followed a normal distribution. The results of the normality test for the initial mathematical aptitude data of students in both learning groups are presented in the following table:

Table 4
The normality test of students’ initial mathematical ability

Kolmogorov-Smirnov	Control	Experiment (AR)
N	15	15
Sig.	0.38	0.50

The significance value (sig.) of the data regarding traditional learning and augmented reality media using Unity 3D is higher than 0.05, indicating that the null hypothesis (H0) holds true. This suggests that the sample data for both groups is derived from a population with a normally distributed distribution. Additionally, Levene's test will be employed to assess if the variance of the initial mathematical aptitudes in the two learning groups is similar. The subsequent table displays the results of the homogeneity test for the students' initial mathematical aptitude in the two learning groups:

Table 5
The homogeneity test of students’ initial mathematical ability

Levene-test	Data	Criteria
N	30	H_0 rejected
Sig.	0.27	

The probability value (sig.) of the data is more than 0.05, as can be seen in the table above. Based on the obtained results, it can be inferred that the null hypothesis H_0 holds true, indicating that there is validity in assuming the equality of variances between the two groups. Additionally, the t-test was employed to ascertain the similarity of the baseline data regarding mathematical aptitude. The table presented displays the findings of the test conducted to assess the comparability of students' fundamental mathematical abilities, considering their learning.

Table 6
The équivalence test of students’ initial mathematical ability

t-test	Data	Criteria
N	30	H_0 accepted
Sig. (2-tailed)	0.33	

Based on the table provided, as the probability value (sig.) is higher than 0.05, the null hypothesis (H0) is accepted. Consequently, it can be concluded that there is no significant difference in the average initial mathematical aptitude between students who received instruction using augmented reality media with Unity 3D and those who received traditional instruction. This finding supports the statement presented in Table

2, suggesting that there are generally no noticeable variances in basic mathematical aptitude between the experimental and control classes.

To further investigate, a two-way ANOVA test will be conducted to examine the disparity in the improvement of mathematical computational thinking abilities among students who undergo learning with augmented reality media utilizing Unity 3D, based on their initial mathematical abilities. Data were descriptively examined to identify the mean, standard deviation, minimum value, and maximum value in order to provide an overview of the two student groups' mathematical computational thinking abilities. The table presents a condensed overview of the results obtained from the descriptive analysis of the students' data concerning their aptitude for mathematical computational thinking in two different lessons.

Table 7
The description of data gain students' mathematical computational thinking ability

Learning	Ability	Mean of Gain	Sd
AR	High	0.93	0.23
	Medium	0.78	0.11
	Low	0.73	0.15
Control	High	0.69	0.13
	Medium	0.64	0.10
	Low	0.61	0.09

As noted in the table above, students who got conventional instruction did not perform any better in terms of their ability to think mathematically and computationally than students who received instruction utilizing augmented reality media and Unity 3D. This indicates that students who received instruction using augmented reality media and Unity 3D had stronger overall average mathematical computational thinking ability than students who received instruction using traditional methods.

The mathematical computational thinking skills of students who were taught using augmented reality media through Unity 3D were compared to those who received traditional instruction. Afterward, the average difference was assessed. The Kolmogorov-Smirnov test was used to determine whether the data were normal. The following table shows the results of the normality test of students' capacity for mathematical computation in the two learning groups:

Table 8
The normality test of data gain students' mathematical computational thinking ability

Kolmogorov-Smirnov	Control	Experiment
N	15	15
Sig.	0.20	0.17
Description	H_0 accepted	H_0 accepted

According to the provided table, the statistical analysis revealed that the significance value for the mathematical computational thinking capacity of the two learning groups was greater than 0.05. Therefore, it was concluded that the null hypothesis was valid. Consequently, both the experimental class and the control class exhibited normally distributed results in terms of students' mathematical computational thinking ability.

Additionally, Levene's test was utilized to assess whether the variance in computational thinking ability between the two sample groups was equal. The results of the homogeneity test, displayed in the table, indicate the outcomes of this analysis for the students' capacity for mathematical calculation in the two learning groups.

Table 9
The homogeneity test of data gain students' mathematical computational thinking ability

Levene-test	df1	df2	Sig.
10,727	5	24	0.82

The homogeneity of data variance, as indicated in the table, did not show a significance value lower than 0.05. This suggests that the null hypothesis is likely to be true. Moving forward, the aim is to assess whether there is a notable difference in the average mathematical computational thinking ability between students who underwent learning with augmented reality media using Unity 3D and those who followed traditional learning methods. It should be noted that the data on mathematical computational thinking ability for both learning groups adhere to the assumptions of normality and homogeneity of variance. The statistical hypothesis as follows:

H_0: $\mu_1 = \mu_2$
H_1: $\mu_1 > \mu_2$
Description:

μ_1 : The normalized average gain of experimental class computational thinking ability

μ_2 : The normalized average gain of control class computational thinking ability

The following table displays the results of the calculation.

Table 10
The two-way Anova test of data gain students' mathematical computational thinking ability

	sum of squares	df	Average square	F	Sig.	H_0
IMA	7646.67	2	3823.33	7.18	0.00	Rejected
Error	1668.00	24	69.50			
Total	1322.17	30				

The table clearly demonstrates that the learning factors utilized by each learning group had a notable influence on the students' proficiency in mathematical computational thinking. This is evident from the significance value of 0.00, which is lower than the accepted threshold of 0.05. Hence, considering the students' initial mathematical abilities, there was a noteworthy distinction in the average mathematical computational thinking ability between those who were taught using augmented reality media with Unity 3D and those who underwent traditional teaching methods.

According to Hendriyani et al. (2019), Augmented reality technology has the ability to create complex 3D models, which can pose a difficulty for students to visualize in a traditional classroom, on a computer screen, or in their minds. The utilization of augmented reality technology in education offers numerous advantages, such as substantial enhancements to the learning experience and promising potential for educational purposes (Sa'diyyah et al., 2021). The presentation of augmented reality media on triangle and quadrilateral materials is illustrated in the following figure:

Figure 1
Augmented Reality view on triangles and quadrilaterals

Information:
Segitiga : Triangle
Segiempat : Quadrilaterals
Persegi : Square
Luas Persegi Panjang : Rectangular area
Contoh Soal : Problem Example

Augmented reality (AR) is a type of media and human interaction that presents unique experiences to its users. One advantage of AR is its ability to deliver lifelike visual effects through animated imagery. The study conducted on the use of augmented reality as an educational tool has highlighted its positive influence on enhancing students' mathematical computational thinking ability. The impact of this technology on students' mathematical skills was found to be substantial, especially when considering their initial mathematical proficiency level. Examples of the outcomes of the experimental class's computational thinking mathematical test and the outcomes of student interviews are provided below:

1) Decomposition
Q: What do you know from the first question?
S: The sides of the triangle, the perimeter of triangles a, b, and c.

Pattern recognition
Q: What are a, b, and c?
S: a is the first term because the number pattern is two levels, so b is the first difference, and c is the second difference.
Q: What steps did you take when answering the first question?
S: Looking for the truth of the data.

2) Abstraction and generalization of patterns
Q: How?
S: First, look for the difference and then use the formula for the pattern Un two-level number, and the result is 48m.

Q: How do I find the pattern?
S: Use the previous formula again and enter the values of a, b, and c for
get the pattern.

3) Algorithm thinking
Q: What results did you get?
S: The pattern is $12n^2$
Q: How much does it start with?
S: n is 1.

Based on the results of student answers and interviews, students were able to meet the indicators of computational thinking (decomposition) well, namely identifying the information that was known and what was asked of the questions seen in the answers of students who wrote down information about what was known from the questions and when interviewed students said what the meaning of the information he wrote. Students were also able to meet the indicators of computational thinking (pattern recognition) well, namely recognizing the same/different patterns or characteristics in solving the problems given. It can be seen from the student's way of thinking in the answers that students used the formula for the Un pattern of two-level numbers, and when interviewed, students can mention what steps they took at the beginning to solve problem number 1.

In addition, students were also able to meet the indicators of computational thinking (abstraction and generalization of patterns) well in question number 1, seen from the answers of students that they looked for the difference from the circumference of the triangle first. At the time of the interview, the student answered that he was looking **to** the perimeter of the 20th triangle, whether 48 m or not. After that, he looked for the pattern. Students were able to fulfill the indicators of computational thinking (thinking algorithms) well in question number 1. Students mentioned the patterns they used when answering the questions given. In the student's answer when writing his conclusion, he did not write down his statement starting from how many. However, when interviewed, the students knew and answered the statement. On the indicators of computational thinking (algorithm thinking), students were only negligent in drawing conclusions.

Students' mathematical computational thinking abilities are positively impacted by the learning process using augmented reality media created with Unity 3D, especially for flat content. This was demonstrated by the experimental class's 81 overall average score on tests of mathematical computational thinking. Based on their initial mathematical ability, this demonstrates that the experimental class's average computational thinking ability is higher than the control class's average computational thinking ability. However, the biggest challenge is making the transition to feeling comfortable using AR media formats and platforms, which are still relatively new in the classroom. The conclusion drawn is that the students in the control class had not been able to meet the computational thinking indicators (decomposition) well, namely in determining what information was known and what was asked from the questions, came from the results of the control class students' answers. When students were interviewed, those who did not take notes about what was learned through the questions provided insufficient replies. They discussed the information that was available. While students could recognize the same or different patterns or characteristics when solving the questions, they were less able to meet the indicators of computational thinking (abstraction and generalization of patterns) well on the questions and were also unable to meet the indicators of computational thinking (algorithm thinking). Students were able to describe the patterns they employed, while responding to the questions asked, as can be observed from their replies. However, when making conclusions, the answers were incorrect.

Based on their baseline mathematical abilities, students' computational thinking skills can be improved by applying learning through augmented reality. It should be realized that computational thinking ability have a clear relationship with critical thinking ability. Therefore, someone who has good computational thinking ability will usually be more critical in solving mathematical problems. Hence, when someone is accustomed to computational thinking, it is likely that someone is trained to critical thinking. On the basis of this connection, it is necessary to do future research on the application of learning using augmented reality to improve students' critical thinking ability based on initial mathematical abilities.

During the learning process, the researchers saw that male students were more enthusiastic about using AR media. In this instance, their enthusiasm could be shown in three ways: 1) they were more active in asking questions, 2) they were more eager to move forward and explain the outcomes of the exercises, and 3) they were more eager to advance AR applications. The researcher believes that, in order to develop students' capacity for critical thought, it is crucial to take gender into consideration while implementing learning via AR media. The hypothesis that gender influences student learning results is also supported by this.

CONCLUSION

Based on the findings from data processing, analysis, and previous discussions, the following conclusions can be drawn: The enhancement in students' mathematical computational thinking skills is more significant when they learn using augmented reality media compared to conventional learning, considering their initial mathematical abilities. This suggests that the initial mathematical skills of individual students play a role in distinguishing their abilities in mathematical computational thinking between those who receive augmented reality-based learning and those who receive conventional learning methods. Furthermore, it is necessary to examine how the effect of learning with augmented reality media on other mathematical abilities, especially on higher order thinking ability. This research is only limited to flat shapes (triangles and quadrilaterals), hence it is suggested that future research will further develop learning with augmented reality media on other materials. In addition, the research samples taken are only 30 students, so the results of this study are not necessarily in accordance with other junior high schools which have different student characteristics. It is hoped that future researchers can use a larger sample with the aim of strengthening generalizations.

REFERENCES

Alfina, A. (2017). Berpikir komputasional siswa dalam menyelesaikan masalah yang berkaitan dengan aritmetika sosial ditinjau dari gender. *Simki-techsain*, *1*(4), 2–6.

Angraini, L. M., Kusumah, Y. S., Dahlan, J. A. (2019). The Improvement of mathematical generalization reasoning of university students by concept attainment model. *Journal of Physics: Conference Series*, 1280(4), 042011.

Ananda, T. A., Safriadi, N., & Sukamto, A. S. (2015). Penerapan augmented reality sebagai planet-planet di tata surya. *Jurnal sistem dan teknologi informasi*, *1*(1), 1–6.

Arifitama. (2017). Panduan mudah membuat augmented reality. Yogyakarta: Andi.

Cahdriyana, R. A., & Richardo, R. (2020). Berpikir komputasi dalam pembelajaran matematika. *Literasi (Jurnal Ilmu Pendidikan)*, *11*(1), 50. https://doi.org/10.21927/literasi.2020.11(1).50-56

Cansu, F. K., & Cansu, S. K. (2019). An overview of computational thinking. *International journal of computer science education in schools*, *3*(1), 17–30. https://doi.org/10.21585/ijcses.v3i1.53

Città, G., Gentile, M., Allegra, M., Arrigo, M., Conti, D., Ottaviano, S., Reale, F., & Sciortino, M. (2019). The effects of mental rotation on computational thinking. *Computers and Education*, 14(1), 0–10. https://doi.org/10.1016/j.compedu.2019.103613

Doleck, T., Bazelais, P., Lemay, D. J., Saxena, A., & Basnet, R. B. (2017). Algorithmic thinking, cooperativity, creativity, critical thinking, and problem solving: exploring the relationship between computational thinking skills and academic performance. *Journal of computers in education*, *4*(4).

Durak, H. Y., & Saritepeci, M. (2018). Analysis of the relation between computational thinking skills and various variables with the structural equation model. *Computers & education*, 116, 191 - 202.

Efendi, R. (2020). Rancang bangun aplikasi augmented reality untuk deteksi pengenalan tanaman obat berbasis android. *IKRA-ITH Informatika*, *4*(1), 35–45.

Estheriani, N. G. N., & Muhid, A. (2020). Pengembangan kreativitas berpikir siswa di era industri 4.0 melalui perangkat pembelajaran dengan media augmented reality. *Insight: jurnal ilmiah psikologi*, *22*(2), 118. https://doi.org/10.26486/psikologi.v22i2.1206

Fan, W., & Liang, Z. (2012). An overview of the development and application of augmented reality technology. *Computer Knowledge and Technology*, *34*, 8319-8325

Fajri, M., Yurniawati, & Utomo, E. (2019). Computational thinking, mathematical thinking berorientasi gaya kognitif pada pembelajaran matematika di sekolah dasar. *Dinamika matematika sekolah dasar*, 1(1), 1–18.

Fitri Ayu, Suryani, D., Muhammad, & Maria, S. (2022). Pemanfaatan augmented reality sebagai media pembelajaran di masa pandemi pada mata kuliah desain grafis. *Journal of information technology and computer science (INTECOMS)*, *5*(1), 123–131.

Fukuda, K. (2019). Science, technology and innovation ecosystem transformation toward society 5.0. *International journal of production economics*. https://doi.org/10.1016/j.ijpe.2019.07.033

Gall, M., Gall, J., & Borg, R. (2007). Educational research: an introduction (8th ed.). New York, NY: Pearson education.

Gais, Z., & Afriansyah, E. A. (2018). Analisis kemampuan siswa dalam menyelesaikan soal high order thinking ditinjau dari kemampuan awal matematis siswa. *Mosharafa: jurnal pendidikan matematika*, *6*(2), 255–266. https://doi.org/10.31980/mosharafa.v6i2.313

Hanafi, M., Wulandari, K. N., & Ni'mah. (2019). Analisis kemampuan siswa dalam menyelesaikan soal high order thinking ditinjau dari kemampuan awal matematis siswa. *Seminar nasional pendidikan matematika (SNP2M)*, 46–55.

Haryanto, E. V., Lubis, E. L., Saleh, A., Fujiati, Izzah, N. (2018). Implementation of augmented reality of android based animal recognition using marker-based tracking methods. *JISA*, *3*(1), 1-6.

Hendriyani, Y., Effendi, H., Novaliendry, D., & Effendi, H. (2019). Augmented reality sebagai media pembelajaran inovatif di era revolusi industri 4.0. *Jurnal teknologi informasi dan pendidikan*, *12*(2), 63–68. https://doi.org/10.24036/tip.v12i2.244

Humpreys, S. (2015). Computational thinking, a guide for teacher. computing at school. *Charlote BCS*. The chartered institue for IT.

Hu Tianyu et al. (2017). Overview of augmented reality technology. *Computer knowledge and technology, 34,* 194-196.

Idhami, R., Amri, & Aswandi. (2020). Rancang bangun aplikasi augmented reality sebagai media penawaran desain interior berbasis android. *Jurnal teknologi rekayasa informasi dan komputer*, *3*(2), 13–19.

Kadarwati, S., Suparman, S., & Astutik, K. (2020). Keefektifan computational thingking dan problem-based learning dalam meningkatkan kreativitas siswa. *Jurnal karya pendidikan*, *7*(1), 63–68. http://103.97.100.145/index.php/JPMat/article/view/5594

Kawuri, K. R., Budiharti, R., & Fauzi, A. (2019). Penerapan computational thinking untuk meningkatkan kemampuan berpikir kritis siswa kelas X SMA negeri 1 Surakarta pada materi usaha dan energi 6. *Jurnal materi dan pembelajaran fisika (JMPF)*, *9*(2), 116–121. https://jurnal.uns.ac.id/jmpf/article/view/38623

Kalelioglu, F., Gülbahar, Y., & Kukul, V. (2016). A framework for computational thinking based on a systematic research review. *Baltic journal of modern computing*, 4(3), 583.

Korkmaz, Ö., Çakır, R., Özden, M. Y., Oluk, A., & Sarıoğlu, S. (2015). Bireylerin bilgisayarca düşünme becerilerinin farklı değişkenler açısından incelenmesi (a multi-variable investigation of the computational thinking abilities of individuals). *Ondokuz mayıs universitesi eğitim fakültesi dergisi* (1*9th may university faculty of education journal*), *34*(2), 68-87.

Lee, Y., & Choi, J. (2014). Tideland animal AR: superimposing 3D animal models to user defined targets for augmented reality game. *International journal of multimedia and ubiquitous engineering*, *9*(4), 343-348.

Lee, T. Y., Mauriello, M. L., Ahn, J., & Bederson, B. B. (2014). CT arcade: computational thinking with games in school age children. *International journal of child-computer interaction*, *2*(1), 26–33. https://doi.org/10.1016/j.ijcci.2014.06.003

Lestari, A. C., & Annizar, A. M. (2020). Proses berpikir kritis siswa dalam menyelesaikan masalah PISA ditinjau dari kemampuan berpikir komputasi. *Jurnal* *kiprah*, *8*(1), 46–55. https://doi.org/10.31629/kiprah.v8i1.2063

Maharani, A. (2020). Computational thinking dalam pembelajaran matematika menghadapi era society 5.0. *Euclid*, *7*(2), 86. https://doi.org/10.33603/e.v7i2.3364

Mahendra, I. B. M. (2016). Implementasi augmented reality menggunakan unity 3D dan vuporia sdk. *Jurnal ilmiah ilmu komputer universitas Udayana*, *9*(1), 1–5.

Malik, S. (2018). Peningkatan kemampuan berpikir komputasi siswa melalui multimedia interaktif berbasis model quantum teaching and learning. *Universitas Pendidikan Indonesia*, 1–6. https://doi.org/10.13140/RG.2.2.34438.83526

Mauliani, A. (2020). Peran penting computational thinking terhadap masa depan bangsa Indonesia. *Jurnal informatika dan bisnis*, 1–9.

McNicholl, R.(2018). Computational thinking using code.org. *Hello world*, *4*, 37

Mufidah, I. (2018). Profil berpikir komputasi dalam menyelesaiakan bebras task ditinjau dari kecerdasan logis matematis siswa. *UIN Sunan Ampel Surabaya*, 1–110. http://digilib.uinsby.ac.id/id/eprint/28697

Muntahanah, M., Toyib, R., & Ansyori, M. (2017). Penerapan teknologi augmented reality pada katalog rumah berbasis android (studi kasus Pt. Jashando Han Saputra). *Pseudocode*, *4*(1), 81–89. https://doi.org/10.33369/pseudocode.4.1.81-89

Mustaqim, I. (2016). Pemanfaatan augmented reality sebagai media pembelajaran. *Jurnal pendidikan teknologi dan kejuruan*, *13*(2), 174–183.

Mustaqim, I., & Nanang, K. (2017). Pengembangan media pembelajaran PAI berbasis augmented reality. *Jurnal edukasi elektro*, *1*(1), 36–48.

Norouzi, N., Bruder, G., Bailenson, J., Welch, G. (2019). Investigating augmented reality animals as companions. *IEEE: inspect accession number*, 19264848.

Nugroho, A., & Pramono, B. A. (2017). Aplikasi mobile augmented reality berbasis vuforia dan unity pada pengenalan objek 3D dengan studi kasus gedung M Universitas Semarang. *Jurnal transformatika*, *14*(2), 86-96. https://doi.org/10.26623/transformatika.v14i2.442

Nuraisa, D., Azizah, A. N., Nopitasari, D., & Maharani, S. (2019). Exploring students computational thinking based on self-regulated learning in the solution of linear program problem. *JIPM (Jurnal ilmiah pendidikan matematika)*, *8*(1), 30-41. https://doi.org/10.25273/jipm.v8i1.4871

Nurhasanah, Y., & Putri, D. A. (2020). Pengembangan media pembelajaran digital berbasis augmented reality pada topik klasifikasi hewan berdasarkan habitatnya. *Multinetics*, *6*(2), 86–98. https://doi.org/10.32722/multinetics.v6i2.2794

Nurrisma, N., Munadi, R., Syahrial, S., & Meutia, E. D. (2021). Perancangan augmented reality dengan metode marker card detection dalam pengenalan karakter korea. *Informatika mulawarman*: *jurnal ilmiah ilmu komputer*, *16*(1), 34-44.

https://doi.org/10.30872/jim.v16i1.5152

Partiwi, A. (2019). Pengenalan pemicu pemanasan global menggunakan teknologi augmented reality berbasis desktop. *Jurnal ilmiah teknologi dan rekayasa*, *24*(1), 46–57. https://doi.org/10.35760/tr.2019.v24i1.1933

Prasetyo, H., & Sutopo, W. (2018). Industri 4.0: Telaah klasifikasi aspek dan arah perkembangan riset. *J@ti Undip: Jurnal teknik industri*, *13*(1), 17-28. https://doi.org/10.14710/jati.13.1.17-26

Purnamasari, I., & Setiawan, W. (2019). Analisis kemampuan pemecahan masalah matematis siswa SMP pada materi SPLDV ditinjau dari kemampuan awal matematika. *Journal of medives: journal of mathematics education IKIP veteran semarang*, *3*(2), 207-217. https://doi.org/10.31331/medivesveteran.v3i2.771

Purnomo, A., & Haryanto, H. (2012). Aplikasi augmented reality sebagai alat pengukur baju wisudawan wisudawati di universitas Dian Nuswantoro. *Seminar nasional teknologi informasi & komunikasi terapan*, 23–32.

Putra, M. R. A. L., Mahardhika, G. P., & Putro, H. P. (2019). Penerapan kemampuan problem solving pada siswa SMP menggunakan pendekatan computational thinking berbasis role play. *Jurnal format*, *8*(2), 158–164.

Rachmanto, A. D., & Noval, M. S. (2018). Implementasi augmented reality sebagai media pengenalan promosi universitas Nurtanio Bandung menggunakan unity 3D. *Journal FIKI*, *IX*(1), 29–37.

Rawis, Z. C., Tulenan, V., & Sugiarso, B. (2018). Penerapan augmented reality berbasis android untuk mengenalkan pakaian adat tountemboan. *E-journal teknik matematika*, *13*(1), 30–37.

Rosa, A. C., Sunardi, H., & Setiawan, H. (2019). Rekayasa augmented reality planet dalam tata surya sebagai media pembelajaran bagi siswa SMP negeri 57 Palembang. *Jurnal ilmiah informatika global*, *10*(1). https://doi.org/10.36982/jig.v10i1.728

Rosali, D. F., & Suryadi, D. (2021). An analysis of students' computational thinking ability on the number patterns lesson during the covid-19 pandemic. *Formatif: jurnal ilmiah pendidikan MIPA*, *11*(2), 217–232. https://doi.org/10.30998/formatif.v11i2.9905

Román-González, M., Pérez-González, J. C., & Jiménez-Fernández, C. (2017). Which cognitive abilities underlie computational thinking? criterion validity of the computational thinking test. *Computers in human behavior*, *2*(7), 1-14.

Rusnandi, E., Sujadi, H., Fibriyany, E., & Fauzyah, N. (2016). Implementasi augmented reality pada pengembangan media pembelajaran pemodelan bangun ruang 3D untuk siswa sekolah dasar. *Infotech journal*, 24–31.

Sa'diyyah, F. N., Mania, S., & Suharti. (2021). Pengembangan instrumen tes untuk mengukur kemampuan berpikir komputasi siswa. *JPMI (jurnal pembelajaran matematika inovatif)*, *4*(1), 17–26. https://doi.org/10.22460/jpmi.v4i1.17-26

Saputri, S., & Sibarani, A. J. P. (2020). Implementasi augmented reality pada pembelajaran matematika mengenal bangun ruang dengan metode marked based tracking berbasis android. *Komputika: jurnal sistem komputer*, *9*(1), 15–24. https://doi.org/10.34010/komputika.v9i1.2362

Setyawan, B. (2019). Augmented reality dalam pembelajaran IPA bagi siswa SD. *Jurnal teknologi pendidikan*, *07*(01), 78–90.

Sidik, M. F., & Vivivanti, V. (2021). Penerapan teknologi augmented reality pada media pembelajaran interaktif berbasis android untuk materi instalasi jaringan komputer. *Tematik-jurnal teknologi informasi dan komunikasi*, *8*(1), 14–28. http://jurnal.plb.ac.id/index.php/tematik/article/view/542

Suciliyana, Y., & Rahman, L. O. A. (2020). Augmented reality sebagai media pendidikan kesehatan untuk anak usia sekolah. *Jurnal surya muda*, *2*(1), 39–53. https://doi.org/10.38102/jsm.v2i1.51

Sukamto, T. S., Pertiwi, A., Affandy, Syukur, A., Hafdhoh, N., & Hidayat, E. Y. (2019). Pengenalan computational thinking sebagai metode problem solving kepada guru dan siswa sekolah di kota semarang. *Abdimasku*, *2*(2), 99–107.

Supianti, I. I., Zakiyah, K., & Agustian, F. (2021). E-learning: pencapaian productive disposition berdasarkan kemampuan awal matematis siswa SMP. *JNPM (jurnal nasional pendidikan matematika)*, *5*(2), 310-321. https://doi.org/10.33603/jnpm.v5i2.5331

Sural, I. (2018). Augmented reality experience: Initial perceptions of higher education students. International Journal of Instruction, 11(4), 565-576. https://doi.org/10.12973/iji.2018.11435a

Syarifuddin, M., Risa, D. F., Hanifah, A. I., & Nurussa'adah. (2019). Experiment computational thinking: upaya meningkatkan kualitas problem solving anak melalui permainan gorlids. *Jurnal mitra pendidikan (JMP online)*, *3*(6), 807–822.

Tresnawati, D., Setiawan, R., Fitriani, L., Mulyani, A., Rahayu, S., Nasrullah, M. R., Septiana, Y., Fatimah, D. D. S., Satria, E., Gunadhi, E., Latifah, A., & Sutedi, A. (2020). Membentuk cara berpikir komputasi siswa di Garut dengan tantangan bebras. *Jurnal pkm Miftek*, *1*(1), 55–60. https://doi.org/10.33364/miftek/v.1-1.55

Wahyu, Y., Suastra, I. W., Sadia, I. W., & Suarni, N. K. (2020). The Effectiveness of Mobile Augmented Reality Assisted Stem-Based Learning on Scientific Literacy and Students' Achievement. International Journal of Instruction, 13(3), 343-356. https://doi.org/10.29333/iji.2020.13324a

Wing, J. M. (2017). Computational thinking's influence on research and education for all Influenza del pensiero computazionale nella ricerca e nell'educazione per tutti. *Italian journal of educational technology*, *25*(2), 7–14. https://doi.org/10.17471/2499-4324/922

Yang, H., Mouza, C., & Pan, Y. C. (2018). Examining pre-service teacher knowledge trajectories of computational thinking through a redesigned educational technology course. *Proceedings of international conference of the learning sciences*, *1*, 368–375.

Yadav, A., Gretter, S., Good, J., & McLean, T. (2017). Computational thinking in teacher education. *Emerging research, practice, and policy on computational thinking*, 205-220.

Yadav, A., Mayfield, C., Zhou, N., Hambrusch, S., & Korb, J. T. (2014). Computational thinking in elementary and secondary teacher education. *ACM Transactions on Computing Education (TOCE)*, *14*(1), 5.

Yasin, M. (2020). Asesmen penulisan jurnal untuk meningkatan kemampuan berpikir komputasi. *Journal writing assessment to improve computational thinking ability*, *11*, 1–21.

Yuntawati, Y., Sanapiah, S., & Aziz, L. A. (2021). Analisis kemampuan computational thinking mahasiswa dalam menyelesaikan masalah matematika. *Media pendidikan matematika*, *9*(1), 34. https://doi.org/10.33394/mpm.v9i1.3898

Yustina, Mahadi, I., Ariska, D., Arnentis., & Darmadi. (2022). The effect of e-learning based on the problem-based learning model on students' creative thinking skills during the covid-19 pandemic. I*nternational journal of instruction*, *15*(2), 329-348. https://doi.org/10.29333/iji.2022.15219a.

Zahid, M. Z. (2020). Telaah kerangka kerja PISA 2021 era integrasi computational thinking dalam bidang matematika. *Prosiding seminar nasional matematika*, *3*(2020), 706–713.
https://journal.unnes.ac.id/sju/index.php/prisma/article/view/37991/15997%0Ahttps://journal.unnes.ac.id/sju/index.php/prisma/

Zarzuela, M. M., Pernas, F. J. D., Martinez, L. B., Ortega, D. G., Rodriguez, M. A. (2013). Mobile serious game using augmented reality for supporting children's learning about animals. *Procedia computer science*, *25*, 375-381.

Zhong, Z., Yi, Z., Jiangjian, X. (2015). Overview of VR technology. *Science in china: information science*, *2*, 157-180.

Zulkarnain, I. (2019). Pengaruh kemampuan awal terhadap prestasi belajar matematika siswa. *Jurnal ilmu pendidikan STKIP Kusuma Negara*, *11*(2), 88–94. https://doi.org/10.37640/jip.v11i2.94

Zydney, J. M., Warner, Z., & Angelone, L. (2020). Learning through experience: using design based research to redesign protocols for blended synchronous learning environments. *Computers and education*, *143*, 103678. https://doi.org/10.1016/j.compedu.2019.103678