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Improvement of Computational Thinking through Interactive Multimedia Learning Based on Initial Mathematical Ability

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Abstract: This study was motivated by the low level of computational thinking (CT) ability in students as witnessed by the author among prospective teachers, along with the changes that came about within the learning system in the move from face-to-face to online learning during the COVID-19 pandemic. This study specifically seeks to improve students' mathematical computational thinking ability through the use of interactive multimedia-based teaching materials based on initial mathematical ability to support online learning. This quantitative study (quasiexperimental) was conducted at two universities, namely, Universities Islam Riau (UIR) and Universitas Pasir Pengaraian (UPP) in Indonesia. The research subjects were prospective mathematics teachers taking algebraic structure at the UIR (an experimental class) and the prospective mathematics teacher course at the UPP (control class) in the 2021/2022 academic year. The data were collected method through a computational thinking ability test and interview, and the test results data are processed using a statistical test. Normality is assessed using the Kolmogorov–Smirnov test, and homogeneity is assessed using the Levene and two-way analysis of variance (ANOVA) tests. From the two-way ANOVA test, a significance value of 0.001 < 0.05 was obtained. This indicates that an increase is observed in the mathematical computational thinking ability of students who receive learning using interactive multimedia-based teaching material based on initial mathematical ability.

Keywords: Computational Thinking, Teaching Material, Interactive Multimedia, Online Learning, Initial Mathematical Ability

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1. Introduction

Media is an intermediary tool in the learning process (Fachinger, 2006) (Ferreira, et al, 2018). Learning media constitute a component of learning resources that contain instructional materials for the student, and they can stimulate students to learn. Thus, the purpose of using media in the learning process is to streamline the learning process (Al Faruqi, 2019) (Salgues, 2018) (Heliany, 2019).

Multimedia refers to media that combines disparate elements, such as audio, visual, audiovisual, animation, text, graphics, images, and photos in an integrated manner (Fikri & Madona, 2018). Media can introduce information from sources, such as lecturers or educators, to students (Daryanto, 2016); the benefits of media are as follows: a) explaining messages in ways that go beyond the verbal; b) overcoming the limitations of space, time, energy, and the senses; c) fostering a spirit of learning and a more direct interaction between students and teachers; d) making students learn independently according to their visual, auditory, and kinesthetic talents and abilities; e) giving the same encouragement; and f) applying the five components of the learning process: communication, teachers, learning material, learning media, students, and learning objectives. Multimedia learning can be interpreted as an application of multimedia that is used in the learning process, in other words, for delivering messages (knowledge, skills, and attitudes) and stimulating the choices, feelings, hearts, and desires of students to encourage the learning process to go on intentionally, purposefully, and under control (Munir, 2014).

Multimedia can be grouped into two types, namely, linear multimedia and interactive multimedia. Linear multimedia incorporates a series of sequential stories. This scheme displays screens one after another sequentially according to a set of rules. Linear multimedia can be interpreted as multimedia that is not equipped with any controller that can be operated by the user. Here, the multimedia is running sequentially/straight, as in television and movies. Conversely, interactive multimedia is multimedia that is equipped with controllers such as tools in the form of computers, mice, keyboards, and others that can be operated by users, allowing the users to choose what they would like next, such as in game applications (Trinawindu, 2016).

Interactive multimedia provides great benefits to learning (Nazar, et al., 2020) (Ilyasa & Dwiningsih, 2020) (Mumtaha & Khoiri, 2019). Interactive multimedia is equipped with a controller that can be operated by the user that allows the user to choose one or another thing in the next process. The use of interactive multimedia is not limited by space and time, so it provides its own learning motivation for the students (Atibrata, 2019) (Anggareni, et. al., 2019) (Istigfar et. al., 2018) (Ferry & Kamil, 2019) (Riyanto & Susilawati, 2019) (Wilsa, 2019) (Prasojo et. al., 2018) (Sadikin & Hakim, 2019).

Daryanto (2016) described interactive multimedia as multimedia that is equipped with a controller and can be operated by the user so that the user can choose as to the next event in the learning process to occur. Arham and Dwiningsih (Arham & Dwiningsih, 2016) found that interactive multimedia is a necessary modification for a learning medium in accordance with advances in technology and information. Interactive multimedia is multimedia that is equipped with a controller element for users (Firmansyah, 2019).

The development and use of media in the learning process can streamline the learning process itself (Sadikin & Hakim, 2019), (Muhaimin et. al., 2019) (Mukmin & Primasatya, 2020) (Sadikin et. al., 2020) (Kusmanagara et. al., 2018) (Sembiring et. al., 2018). Several studies have found that the use of interactive multimedia is an effective means of helping students make scientific information easier to understand through a visual presentation of information.

Interactive multimedia-based teaching materials can replace lecturers in the classroom, allowing students to understand materials and ask questions that train computational thinking (CT). Interactive multimedia-based teaching materials are needed to train computational thinking ability, especially during the pandemic. Interactive multimedia exhibits a combination of text, images, animation, sound, and video that involves many senses in the learning. This approach can make it easier for students to understand the material because the more senses are involved in the learning process, the more effective the learning will be. Using interactive multimedia, users can adjust the learning process to fit the speed of their understanding.

The term computational thinking refers to a problem-solving technique that takes a wide scope, not only with respect to the solution of problems around computer science and mathematics but also to solving various problems in everyday life (Rosadi et. al., 2020) (Cahdriyana & Richardo, 2020) (Zahid, 2020). Using computational thinking, students can learn how to think logically, structurally, and critically. Computational thinking is a very important skill for students because it can help them structure and solve complex problems (Sukamto, et. al., 2019) (Syarifudin, 2019) (Fajri et. al., 2019) (Putra et. al., 2019) (Alfina, 2017).

Adler and Kim (Adler & Kim, 2018) suggested that strengthening computational thinking will be beneficial for students in their education and their future. Rachim (2015) found that computational thinking is a cognitive ability that allows students to describe patterns, break complex problems into small steps, and organize and create a series of steps to provide solutions and build data representations through simulations.

The characteristics of computational thinking are as follows: formulating new problems by breaking down larger problems into smaller parts to make them easier to solve (Lestari & Annizar, 2020) (Tresnawati, et al., 2020). This allows students to turn complex problems into several smaller procedures or steps that are both easier to solve and also provide an efficient way to think critically (Syarifuddin, 2019) (Lestari & Annizar, 2020) (Kadarwati, et al., 2020).

Computational thinking can increase the ability to think logically, structurally, and critically. Furthermore, computational thinking entails the use of algorithms, whereby we think by sequencing the steps in solving problems so that they become logical, sequential, orderly, and easily understood by others. Students should have computational thinking because it improves their thinking ability in general (Kawuri, et al., 2019) (Roman, et. al., 2017). The characteristic of computational thinking are needed to understand the lectures given in a university-level algebraic structure course. This course contains algebraic concepts that require students to practice higher-order thinking in problem solving. The course emphasizes giving student sufficient time to solve problems ranging from simple problems to quite complex ones.

Several researchers have argued that mathematical thinking plays an important role in computational thinking rather than the other way around (Roman, et. a., 2017). Computational thinking ability makes a strong contribution to problem-solving ability (Grover, et. al., 2015)). Lee et. al. (2014) suggested that computational thinking can prompt students to think logically, structurally, and systematically. Drawing on computational thinking, students can learn how to think logically, structurally, and critically (Anggraini & Wahyuni, 2021) (Hariadi, et. al., 2022). Kulles (2016) said that students' critical thinking ability has a relationship with computational thinking concepts, namely, the concepts of algorithmic thinking and abstraction.

Many authors (Roman, et. al., 2017), (Nurmuslimah, 2020) (Gover & Pea, 2018) (Tabesh, 2017) (Gadanidis, 2017) (Sung, et. al., 2017) (Kale, et. al., 2018) described four broad computational thinking abilities, namely, problem decomposition, pattern recognition, abstraction, and generalization into patterns, as well as thinking with algorithms. According to Mohaghegh and McCauley (Mohaghegh & McCauley, 2016), computational thinking has the following characteristics: 1) ability to problem solve using computers or other devices; 2) ability to organize and analyze data; 3) ability to perform data representation through abstraction with a model or simulation; 4) ability to automate solutions through algorithmic thinking; 5) ability to identify, analyze, and implement solutions using various combinations of steps/methods and efficient and effective resources; and 6) ability to generalize solutions to a variety of different problems.

Computational thinking ability can be improved through interactive multimedia-based teaching materials (Yang, et. al., 2018) (Fukuda, 2019) (Prasetyo & Sutopo, 2018). The application of multimedia can help achieve learning objectives (Mukmin & Zunaidah, 2018) (Purnomo, et. al., 2020) (Garcia, et. al., 2017) (Darimi, 2017) (Kurniawati, 2018). Multimedia in learning is useful for delivering knowledge and skills, and it can also stimulate students' attention and interest so that learning becomes more directed and controlled.

Research on computational thinking ability has been conducted by Kadarwati (2020), who identified the effectiveness of computational thinking in increasing students' creativity. Cahdriyana and Richardo (2020) showed the relevance of computational thinking ability to mathematics learning. Zahid (2020) indicated the integration of computational thinking into mathematics. Tresnawati (2020) described the computational thinking of students with free challenges. A study of interactive multimedia-based teaching materials that can make learning more effective and efficient has been conducted by Sadikin and Hakim (2019), who developed interactive e-learning media to welcome Industrial Revolution 4.0. Panjaitan (2020) described the use of game-based interactive multimedia education as a medium for learning. Nazar (2020) developed an Android-based interactive learning application to help students in learning, and Ilyasa and Dwiningsih (2020) showed that using an interactive multimedia model based on unity can improve learning outcomes. This study relates learning using interactive multimedia-based teaching materials to improve students' computational thinking ability, which is a novelty, as so far research has not found the application of interactive multimedia, in this case using Quizizz as a tool to complete practice questions from algebraic structure course materials, linked to improving computational thinking ability.

Interactive multimedia-based teaching materials that package material, examples, and practice questions, arranged according to the indicators that must be achieved to improve students' computational thinking ability based on initial mathematical ability (IMA), are a novelty in this research. Conversely, it is acknowledged that students' mathematical ability can also distinguish their computational thinking ability, so this study seeks to improve computational thinking ability through interactive multimedia-based teaching materials based on initial mathematical ability to support online learning.

2. Methodology

This study was conducted at two universities, namely, Universitas Islam Riau (UIR) and Universitas Pasir Pengaraian (UPP), for students majoring in mathematics education who are taking the algebraic structure course in the 2021/2022 academic year. These groups at the UIR and UPP were chosen because (1) both groups have homogeneous variances; (2) better generalization results can be obtained with the use of this sample; (3) the UIR and UPP have established collaboration in the field of research; and (4) lecturers who teach the algebraic structure courses at the UIR and UPP conduct intense communication on problems in algebraic structure lectures and some of the same problems are found, including the low level of computational thinking in students. The subjects of this study were 32 students divided into two classes: experimental and control. The experimental class was given instruction using interactive multimedia-based teaching materials, whereas the control class was given teaching materials in the form of student worksheets (SWs). Each teaching material aims to form effective learning so that students have better computational thinking skills. The student worksheets used in the control class are also arranged according to stages that must be achieved in computational thinking ability. The difference between the two goals is that the experimental class uses interactive multimedia, which is structured by taking into account the stages of computational thinking, whereas the control class uses student worksheets that have the same content and exercises but the stages in the student worksheets also refer to aspects of computational thinking that must be achieved. The student worksheets is also structured as attractively as possible taking into account problems that have been encountered by students.

This research method is experimental, and the study is conducted to identify the effects of certain treatments. This study was a quasi experimental nonequivalent control group, as the students who were the respondents in this study were not randomly selected, but the researchers randomized existing classes. This study looks at the effects of learning based on initial mathematical ability. High mathematical ability tends to appear together with a high level of thinking ability and vice versa. Low mathematical ability tends to show a low level of thinking ability as well. Thus, this study looks at students' initial mathematical ability as a determining factor in distinguishing the increase in students' computational thinking ability through interactive multimedia-based teaching materials to support online learning.

The research data were collected through tests and interviews. The test is given in the form of questions about computational thinking ability. The test was first validated by experts. Then, the data were analyzed using the two-way analysis of variance (ANOVA) test. Before going to the two-way ANOVA test, the data were tested for an assumption test, in this case, to ensure that the data receive tests of normality and homogeneity. The normality test used the Kolmogorov–Smirnov test, and the homogeneity test used the Levene test.

3. Findings and Discussion

Computational thinking is thinking using algorithms, in which thinking is done by sequencing the steps in solving problems so that they become logical, sequential, orderly, and easily understood by others. Acquiring computational thinking ability is important for students because it allows them to develop superior thinking abilities (Kawuri, et. al., 2019) (Maharani, 2020].

With computational thinking, students can learn how to think logically, structurally, and critically. Computational thinking is very important for students to help them structure solving complex problems (Sukamto, et. al., 2019) (Syarifuddin, 2019) (Fajri, et. al., 2019) (Putra, et. al., 2019) (Alfina, 2017). Table 1 presents the results of data processing of students' computational thinking ability.

Table 1. Distribution of research samples

Initial mathematical ability	Control	Experiment	Sum
High	5	5	10
Medium	6	6	12
Low	5	5	10
Sum	16	16	32

The initial mathematical ability of students consists of three categories, namely, high, medium, and low. Initial mathematical ability data were collected and analyzed to determine the students' initial mathematical ability before this research was conducted. The initial mathematical ability results, which are used as data on the initial mathematical ability, are then grouped based on the categories of high, medium, and low initial ability.

Table 2. Normality test

Class	P-value
Experiment	0.431
Control	0.722

In Table 2, the p-value of the experimental class is 0.431 > 0.05, and the p-value of the control class is 0.722 > 0.05. It can be concluded that the mathematical computational thinking ability of experimental class students and control class students are normally distributed at a significance level of 0.05. Furthermore, Table 3 shows the results of the homogeneity test.

Table 3. Homogeneity test

Levene statistic	df	P-value
1,626	26	0.207

As shown in Table 3, the p-value is 0.207 > 0.05. This means that the two learning groups have homogeneous variances. Furthermore, Table 4 shows the results of the two-way ANOVA test.

Table 4. Two-way analysis of variance test

Two-way analysis of variance test	P-value
Learning	0.001
IMA	0.001
Interaction	0.276

As shown in Table 4, the p-value is 0.001 < 0.05. This means that the improvement in the mathematical computational thinking ability of students who receive interactive multimedia-based teaching materials is better than that of students who receive conventional learning based on initial mathematical ability.

The results show that there was an increase in the mathematical computational thinking ability of students who were taught using interactive multimedia-based teaching materials. Media is an intermediary tool in the learning process (Fachinger, 2017) (Al Faruqi, 2019) (Ferreira, et. al., 2018. Learning media is a component of learning resources that contain instructional materials that can stimulate students to learn. Thus, the purpose of using media in learning is to streamline the learning as conducted by lecturers (Al Faruqi, 2019) (Salgues, 2018) (Heliany, 2019). Interactive multimedia provides significant benefits to learning (Nazar, et. al., 2020) (Ilyasa & Dwiningsih, 2020) (Mumtaha & Khoiri).

In the learning process, as can be seen from the results of observations made during the study and as confirmed by the results of interviews, the students were very enthusiastic about participating in learning using interactive multimedia-based teaching materials. The following excerpts provide such confirmation:

Q : How do you find learning using-based teaching materials interactive multimedia?
A : It is fun, we are happy because the material is packaged interactively, and practice using Quizizz feels like playing games.
Q : How did you enjoy the learning materials?
A : The material is difficult, but it is not boring, as it feels like learning while playing games.
Q : Would you agree to have the material in the algebraic structure course packaged in the form of interactive media?

A : I would agree, but we need a more stable internet connection.
Q : Did you have difficulty understanding the material? algebraic structure after being packaged with interactive media?
A : Some materials were still difficult to understand, but we tried to understand everything.

During their study, the active students were not only those with high initial mathematical ability but also those with moderate and low initial mathematical ability. Among the obstacles that arose during the study were that most students had problems with the internet connection, were living outside of urban areas with inadequate internet network quality and had few choices of providers that could be chosen according to the costs they had. However, initial mathematical ability had a significant influence on online learning, causing different levels of increase in the mathematical computational thinking ability between students who are taught using interactive multimedia-based teaching materials and students who are taught using conventional learning.

Conversely, although the computational thinking ability of students taught with interactive multimedia was greater than that of those who were taught conventionally, the interaction between learning used with initial mathematical ability showed no effect on students' mathematical computational thinking ability. Figure 1 presents a display of learning media using interactive multimedia-based teaching materials.

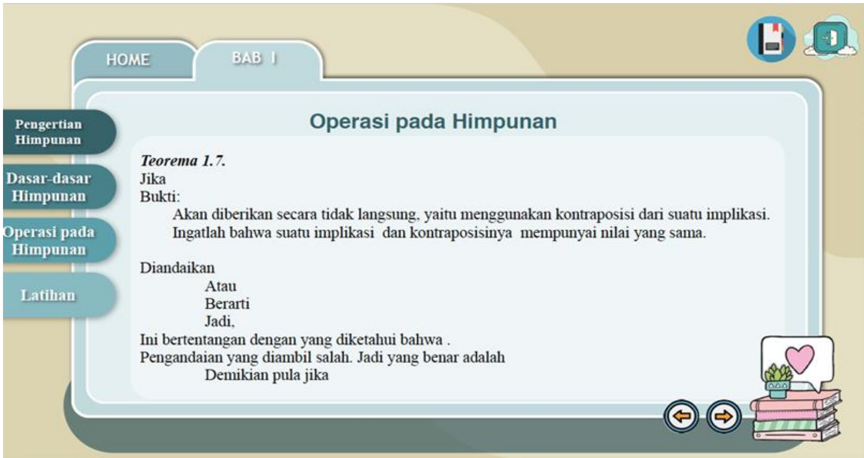

Fig. 1. Display of interactive multimedia-based teaching materials

The interactive multimedia provided contains the following: (1) prerequisite materials that aim to stimulate students' initial abilities, (2) core materials aimed at inculcating the concepts that are to be learned, and (3) practice questions to apply the concepts that the students learned that day. The buttons in the display above have the following functions: (1) the back button leads the user to the previous material so that students who forget the concepts they are learning can open their material quickly; (2) the home button displays to students the meeting materials that they will study, which makes it easier for students who can learn faster than others, thereby minimizing the boredom they experience; and (3) the practice button is directly connected to Quizizz so that students can participate in exercises such as playing games, making their boredom disappears and replacing it with curiosity and enthusiasm to complete the practice questions to bring them to the finish point. Figure 2 represents the implementation of the experimental class study.

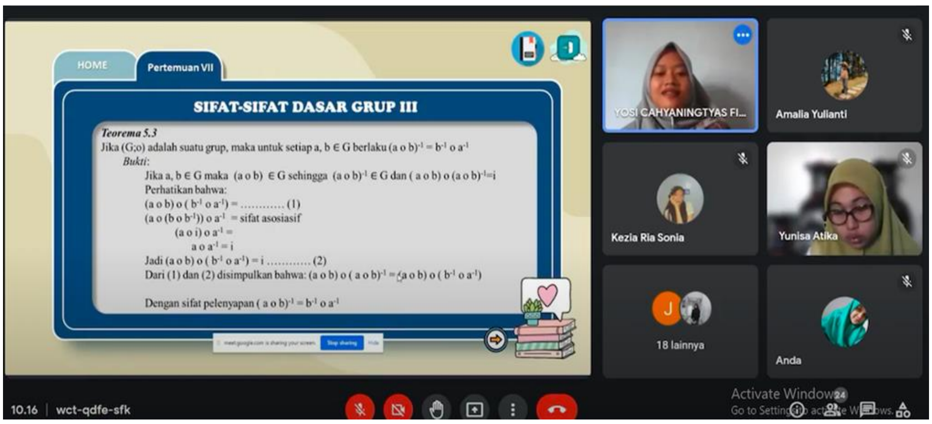

Fig. 2. Experimental class learning process

This learning process takes place using interactive multimedia-based teaching materials. During their lesson, students enthusiastically participated in participating in responding to practice questions given by the lecturer. They took turns offering to answer the exercise. The experimental class uses interactive multimedia that is structured by taking into account the stages of computational thinking, whereas the control class uses student worksheets whose material content and exercises remain the same as for classes without the multimedia portion, whereas the stages in the student worksheets also refer to aspects of computational thinking that must be completed by students. The student worksheets are also structured as attractively as possible, taking into account the problems that have been experienced by students. The student worksheets contain prerequisite material to stimulate the initial ability of students in the control class; the core material aims to inculcate the concepts that must be learned and practice questions that are intended to use to apply the concepts that they learned that day. The content of the material and exercises remains the same, and the only difference is the use of media. Figure 3 displays the results of the posttest for the experimental class.

Agar $(G, *)$ dikatakan sebagai grup dalam operasi $*$, maka harus ditunjukkan bahwa $(G, *)$ memenuhi 4 aksioma grup (termasuk sifat tertutup).

Aksioma 1: Ketertutupan

Akan ditunjukkan bahwa operasi $*$ bersifat tertutup pada G.

Ambil sembarang $a, b \in G$ sehingga menurut definisi operasi $*$, diperoleh $a * b = \frac{ab}{2}$. Karena ab dan 2 masing-masing merupakan bilangan bulat positif, maka $\frac{ab}{2}$ merupakan bilangan rasional positif sehingga $\frac{ab}{2}$ juga anggota G. Berarti, operasi $*$ bersifat tertutup pada G.

Aksioma 2: Asosiatif

Akan ditunjukkan bahwa operasi $*$ pada G bersifat asosiatif.

Ambil sembarang $a, b, c \in G$. Perhatikan bahwa

$$(a * b) * c = \frac{ab}{2} * c$$
$$= \frac{abc}{4}$$

bc

Aksioma 3: Identitas

Akan ditunjukkan bahwa operasi $*$ pada G memiliki identitas.

Ambil sembarang $a \in G$ dengan e sebagai identitas (yang akan dicari). Perhatikan bahwa

$$a * e = \frac{ae}{2} = a \Rightarrow e = \frac{2a}{a} = 2$$
$$e * a = \frac{ea}{2} = a \Rightarrow e = \frac{2a}{a} = 2.$$

Jadi, unsur identitas/kesatuannya adalah 2.

Aksioma 4: Invers

Akan ditunjukkan bahwa operasi $*$ pada G memiliki invers.

Ambil sembarang $a, b \in G$ sehingga menurut aksioma invers pada grup, invers dari a yaitu b harus memenuhi

$$a * b = 2 \Leftrightarrow \frac{ab}{2} = 2 \Leftrightarrow b = \frac{4}{a}.$$

Jadi, invers sembarang $a \in G$ adalah $\frac{4}{a}$.

Karena memenuhi 4 aksioma grup tersebut, maka $(G, *)$ merupakan grup.

(Terbukti) ■

Fig. 3. Alternative answers to the experiment class posttest

Figure 3 represents alternative responses to the posttest results in the experimental class. It can be seen that most students in the experimental class students were able to correctly respond to the questions. The students who studied using interactive multimedia-based teaching materials could do the following: 1) decomposition, or breaking down data, processes, or (complex) problems into smaller parts or manageable tasks; 2) pattern recognition, or the ability to see similarities or even differences in patterns, trends, and regularities in the data for later use in making predictions and presenting data; this can be seen in the ability of students to show (G, *) groups that fulfill the axioms of closedness, association, identity, and inversion; 3) abstraction, or the ability to generalize and identify general principles that produce these patterns, trends, and regularities, as can be seen from students' ability to prove the axioms of closure, associative, identity, and inversion; and 4) algorithm design, or the ability to develop the same step-by-step problem-solving instructions so that other people can use the steps/information to solve the same problem, as can be seen from the student's ability to order the steps that must be met to prove a theorem, namely, first proving the axioms of closure and then proving the associative axioms, the axioms of identity, and the inverse axioms, so that if the four axioms are proven, (G, *) can be concluded.

Several important comments should be related to interactive multimedia-based computational thinking: (1) There was an increase in the mathematical computational thinking ability of students who receive interactive multimedia-based teaching materials relative to students who receive conventional learning as a whole. (2) There was an increase in the mathematical computational thinking ability of students who receive interactive multimedia-based teaching materials relative to students who receive conventional learning based on initial mathematical ability. (3) There was no interaction between the learning used and the initial mathematical ability on the achievement of students' mathematical computational thinking ability.

4. Conclusion

The results of research and discussion in the previous chapter indicate that the following conclusions can be drawn: There is an improvement in the mathematical computational thinking ability of students who received interactive multimedia-based teaching materials relative to students who received conventional learning based on initial mathematical ability. Furthermore, it is necessary to examine the effects of interactive multimedia-based teaching materials on students' mathematical computational thinking ability based on gender. Some researchers consider that mathematical ability varies between genders because of biological differences in the male and female brains. This may be related to the observation that female students generally have higher levels of achievement in language and writing, whereas boys are more capable in mathematics because of their superior spatial abilities.

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