JURNAL EDUSCIENCE (JES)
p-ISSN : 2303 - 355X | e-ISSN : 2685 - 2217
PUBLISHED BY : LPPM of UNIVERSITAS LABUHANBATU

Exploration of Mathematical Abstract Learning Using Tactile and Visual 3D Media: Student Mathematical Abstraction Skill

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ARTICLE INFO

Keywords:
Mathematical Abstract
Learning Activities
Tactile Media
Visual 3D Media
Mathematical Abstraction Skill

ABSTRACT

Purpose: This study aims to explore abstract mathematics learning activities using tactile and 3D visual media, identify the effect of this learning on students' mathematical abstraction skills, and determine the category of students' mathematical abstraction skills.

Methodology-The research approach is mixed method research. The data collection techniques used were observation and testing. The instruments used were observation guidelines and test questions. The qualitative data analysis techniques used were data reduction, presentation, and conclusion. The quantitative data analysis techniques were descriptive tests and paired sample T-tests.

Findings-Mathematical abstract learning activities using tactile media and 3D visual media are: (1) reflection of initial understanding of abstract concepts; (2) orientation towards the use of abstract concepts in everyday life; (3) measuring the surface area and volume of objects using tactile media; (4) connecting measurement results with mathematical formulas; (5) interpretation of abstract concepts using 3D visual media; (6) stating learning experiences or new things obtained; and (7) concluding abstract concepts. There is a strong effect of abstract mathematics learning using tactile media and 3D visual media on students' mathematical abstraction ability. Abstract mathematics learning using tactile and 3D visual media contributes 25.6% to mathematical abstraction ability, while other factors influence 74.4%. There are 11.54% of students with high mathematical abstraction ability, 76.92% with moderate mathematical abstraction ability, and 11.54% with low mathematical abstraction ability.

Significance—These findings can be used as a reference for teachers when teaching abstract mathematical concepts. Teachers should provide more tactile media in learning activities to give students a real experience.

Received 20 January 2025; Received in revised form 25 January 2025; Accepted 22 June 2025
Jurnal Eduscience (JES) Volume 12 No. 3 (2025)
Available online xx June 2025

INTRODUCTION

Mathematics learning is abstract learning. This makes mathematics a complex science (Mukuka & Mutarutinya; V. Balimuttajjo, 2021). The concepts learned in mathematics learning are abstract concepts that state the modeling of a condition or problem into a mathematical form. This abstract concept helps us to solve problems related to everyday life.

Various efforts and media have been developed to make mathematics learning more qualified. However, there are still students who have difficulty learning mathematics. Mangarin and Caballes (2024) said that students have difficulties understanding concepts. Yulita and Ain (2021) also found that students have difficulties using mathematical concepts. Students can only read concepts without understanding the concept's meaning (Maharani et al., 2023).

Observations conducted by researchers show that students have difficulty understanding abstract mathematical concepts. Students only know the definition based on what they have learned in class. When asked to explain the context of using the concept, students could not explain it. Students can use formulas to calculate, but they do not understand the application of these formulas in the context of everyday life problems. This indicates that students only memorize but do not understand.

Understanding abstract mathematical concepts cannot occur if students only memorize them (Khasanah et al., 2021). This is the basis for the need to use media that can connect mathematical concepts with problems in everyday life. The use of these media stimulates students so that they will respond or think to understand the concepts taught.

Students need several stimulations in learning. These simulations are auditory (through hearing), visual (through sight), kinesthetic (through movement), and tactile (through touch) (Adzillina & Hashanah, 2021). Learning abstract concepts helps students visualize complex ideas more effectively (Kansil et al., 2024). Current mathematics learning mostly only focuses on using auditory and visual media. There are still very few mathematics learning media that focus on tactile stimulation.

Tactile stimulation is stimulation given through touch. Touch sensitivity is an important perspective in life activities, especially when creating or interacting with two-dimensional or three-dimensional objects. Touch connects the student's inner understanding and outer world (Friend & Mills, 2021). Tactile media helps students understand abstract mathematical concepts because students will make direct physical contact with the media used.

Yackel (2016) developed learning with tactile (Yackel, 2016)media at the college level. Rahman (2022) has also used tactile media in mathematics learning in Indonesia (Nuraisyah et al., 2021). In his research, Rahman (2022) used textured cards to learn numbers. These textured cards provide tactile stimuli so students can interact directly with their study objects. However, in Indonesia, tactile learning is still sporadic. Thus, learning with tactile media needs to be further studied and developed.

Tactile media also needs to be supported by visual media because mathematical concepts are abstract. Friend and Mills (2021) state that tactile media can be combined with visual media to maximize digital media exploration. This research will combine tactile and 3D visual media to give students a concrete to abstract learning experience (Julianti et al., 2022).

The ability to abstract is the basis and supports the ability to form mathematical concepts (Nurjannah & Kusnandi, 2021). The ability to think abstractly cannot grow directly just by conveying information to students. Students must be exposed to real objects to help them understand abstract mathematical concepts (Savitri et al., 2024). This series of experiences can be realized by involving students in learning media.

The explanation above indicates that students still struggle to understand abstract mathematical concepts. Efforts that can be made to overcome this problem are using tactile media and visual media in learning abstract mathematical concepts. Using tactile and visual media in learning abstract mathematical concepts can help students in abstract thinking (Adawiyah et al., 2023). Both media support each other in providing an understanding of abstract concepts. Tactile media provides students with an experience to learn by directly exploring real objects related to abstract concepts. Visual media gives students an overview of the abstraction of real problems from objects used as tactile media (Maulana et al., 2022).

Several previous studies are relevant to this research. Nurjannah and Kusnandi (2021) studied the role of abstraction abilities in strengthening students' initial knowledge in mathematics learning. Maharani et al. (2023) studied students' abstraction abilities in solving geometry problems. The results of her study showed that students still showed errors in mathematical abstraction. Khasanah et al. (2021) studied students' abstraction abilities based on gender. Her study showed that female students achieved higher abstraction abilities than male students. Previous research was still limited to the analysis of abstraction abilities only. Aktaş (2024) uses origami in geometry learning. The results of his research state that origami can help students with visual impairments in learning geometry. Herman and Naldi (2023) use 3D visual media based on a realistic mathematical approach to learning mathematics in elementary schools. The study's results showed that the media can improve student learning outcomes.

The relevant studies used tactical and visual media to teach basic concepts such as geometry (Maulana et al., 2022). However, no research has used both media simultaneously to teach mathematics about abstract concepts, especially in higher education. Moreover, no research has observed learning activities and media that can affect mathematical abstraction abilities. This study will observe abstract mathematics learning activities using tactile and 3D visual media and their influence on students' mathematical abstraction abilities.

This study aims to explore abstract mathematics learning activities using tactile media and 3D visual media and their effects on students' mathematical abstraction abilities. It is expected to contribute to easy and enjoyable mathematics learning so that abstract concept learning does not feel difficult for students. In addition, this study is also expected to provide a foundation for using real media and visual media for abstract mathematics learning.

METHODOLOGY

Research Design

This type of research is mixed-method research. Mixed method research is a combination of qualitative and quantitative research. Qualitative research is used to observe abstract mathematics learning activities using tactile simulation media and visual simulation. Quantitative research is used to observe the effect of abstract mathematics learning using tactile simulation media and visual simulation on students' mathematical abstraction abilities.

The population in this study were 90 students of the Mathematics Education Study Program at the State Islamic Institute (IAIN) Ambon. The sample used was 26 students of the Mathematics Education Study Program. The sample was selected using a non-probability sampling technique, especially the purposive sampling type. The purposive sampling technique is used to select samples based on specific criteria. The criteria for selecting samples are students who have taken calculus courses. These criteria are sample requirements because samples who have taken calculus courses have previously studied integral material, which is the learning material in this study. The samples were students studying to be more easily coordinated and actively participate in the research.

Data Collection Techniques

The data collection techniques used were observation and testing. Observations were conducted during learning to obtain data on abstract mathematics learning activities using tactile and 3D visual media. The test was used to obtain data on the effect of abstract mathematics learning using tactile and 3D visual media on students' mathematical abstraction abilities. In addition, the test was also used to obtain data on the category of students' mathematical abstraction abilities.

The instruments used were observation guidelines and test questions. The observation guidelines consisted of lecturer and student activity observation guidelines. The lecturer observation guidelines contained 12 preliminary stage statements, core activities, and closing. The observed lecturer activities are as follows.

Table 1. Lecturer Activities Observation

Stage	Activities
Preliminary	1. Opening learning 2. Giving apperception 3. Giving motivation
Core	1. Do exploration with the student 2. Using tactile media in the form of objects that students can touch 3. Using visual media to explain graphs 4. Explaining the materials clearly 5. Using mathematic symbols
Closing	1. Reviewing the learning experience obtained 2. Facilitating students to conclude the material 3. Giving reinforcement about the importance of material in daily life 4. Giving task

Moreover, student observation guidelines consist of 13 statements, each with a general and particular part. The observed student activities are as follows.

Table 2. Student Activities Observation

Part	Activities
General	1. Ready to learn 2. Involved in solving problems given by lecturers 3. Showing enthusiasm
Particular	1. Show attention to the lecturer's explanation 2. Actively ask questions when you do not understand something 3. Active in discussions with friends 4. Using mathematical symbols properly 5. Able to solve problems correctly 6. Able to use tactile media simulated by the lecture in learning 7. Able to explain graph simulated by the lecture

Test questions and observation guidelines were validated using content validity test techniques. A content validity test measures how broadly the material measures the concept being measured. Professional experts in mathematics education carried out validation.

Data Analysis

The data analysis techniques used consisted of qualitative and quantitative data analysis techniques. The qualitative data analysis techniques used were data reduction, presentation, and conclusion. The quantitative data analysis techniques used were descriptive tests and paired sample T-tests. The descriptive test calculated the mean, median, mode, and standard deviation values. Before conducting the paired sample T-test, a normality test was first carried out. The normality test used is the Shapiro-Wilk test. If Sig. If the value is> 0.05, then the data is normally distributed. If Sig. Value < 0.05, then the data is not normally distributed—the paired sample T-test was carried out on the pre-test and post-test values. Students' mathematical abstraction abilities were categorized based on the following criteria (Sugiyono, 2017).

Table 3. Category of Mathematical Abstraction Skill

Category	Criteria
High	$X \geq \mu + 1\sigma$
Medium	$\mu - 1\sigma \leq X < \mu + 1\sigma$
Low	$X < \mu - 1\sigma$

FINDINGS

Activities of Mathematical Abstract Learning Using Tactile Media and Visual 3D Media

The study was conducted on 26 students of the Mathematics Education Study Program. Students were given abstract mathematics learning using tactile media and 3D visual media. The abstract mathematics material taught was integral. The media used consisted of tactile media and 3D visual media.

Tactile media also called touch media, provides students with direct learning experiences through objects that can be touched and explored directly by students. The tactile media used were measuring boards, leaf sheets, and eggplants. The measuring board was used to help students measure the surface area and volume of objects.

Another media used was 3D visual media. This media led students to mathematical abstraction activities after exploring tactile media (touch). The 3D visual media used was Geogebra. This Geogebra software can provide visual displays of 2D and 3D graphics that help students in the mathematical abstraction process.

The abstract mathematics learning activities carried out were: (1) Reflection of the initial understanding of abstract concepts; (2) Orientation toward the use of abstract concepts in everyday life; (3) Measuring the surface area and volume of objects using tactile media; (4) Connecting measurement results with mathematical formulas; (5) Interpreting abstract concepts using 3D visual media; (6) Expressing learning experiences or new things obtained; (7) Concluding abstract concepts. These activities contain mathematical abstraction activities ranging from reflective, empirical, and theoretical abstraction. Reflective abstraction activities involve integrating formulas and problems and transforming problems into symbolic forms. Empirical abstraction consists of generalizing, forming mathematical concepts with other concepts, forming advanced mathematical objects, and formalizing mathematical objects.

Activity 1. Reflection of Initial Understanding of Abstract Concepts

At this stage, the lecturer invites students to recall their initial understanding of the integral concept they previously learned. Several students convey their initial understanding of the integral concept that they know.

Figure 1. Reflection of Initial Understanding

When asked what students know about the integral concept, most are confused. The lecturer provides stimulus to students about the basis of the integral concept. Several students then convey what they know about the integral. The students' initial understanding is still theoretical. Students understand the integral as a formula that has a specific solution. Students can explain the procedure for calculating the integral but cannot state its meaning.

Activity 2. Orientation Towards the Use of Abstract Concepts in Everyday Life

At this stage, the lecturer asked students to express their opinions regarding the application of integrals in everyday life. Students answered well, namely by stating that integrals are used to calculate objects' surface area and volume. It is just that students understand this based on memorization of previously studied material. Students have not been able to explain examples of the application of integrals in everyday life.

Figure 2(a) and 2(b). Orientation of the Use of Abstract Concepts in Everyday Life

Activity 3. Measuring The Surface Area and Volume of Objects Using Tactile Media

At this stage, the lecturer guides students together to calculate the surface area and volume of objects using tactile media. Students explore the tactile media used to calculate the area and volume in groups. Leaves are used to measure the surface area, while eggplant is used to measure the volume of objects.

Figure 3(a), 3(b), 3(c). Measuring Surface Area with Tactile Media

The image above shows student activities for measuring the surface area of leaves. The tool used to measure the surface area of leaves is a square measuring board, each box having a side length of 1 cm. Students draw the shape of a leaf on the measuring board. The following are the results of the leaf image on the measuring board.

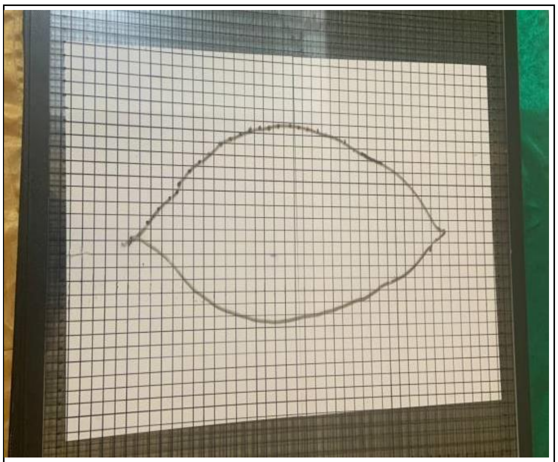

Figure 4. Measuring the Surface Area of Objects with the Riemann Sum Approach

Students will calculate the surface area of leaves based on the image above. The surface area of leaves is calculated using the Riemann sum, using the area of each partition. The total area of each partition is then added up to get the surface area. The lecturer directs students to understand the usefulness of the Riemann sum in measuring the surface area of irregular objects.

In addition to measuring the surface area of objects, students also carried out volume measurement activities using eggplant media. The volume of objects (eggplant) was measured using the disc method. The principle of the disc method is to divide the object into disc pieces. The volume of each piece will be calculated using the volume of the cylinder $V = \pi r^2 t$.

Figure 6 (a), 6 (b), 6 (c). Measuring the Volume of Objects with Tactile Media

The image above shows student activities in measuring the volume of objects with tactile media (eggplant). Students divided the eggplant into small pieces with a width of 1 cm each. The volume of each piece was calculated using the volume of the cylinder. The volume of each piece was then added together to produce the total volume of the eggplant.

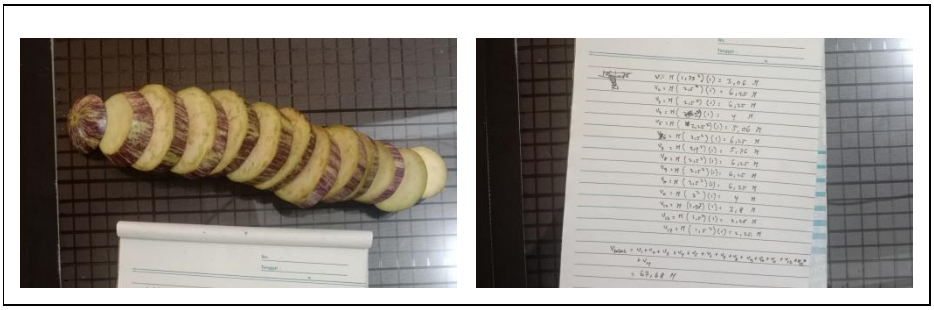

Figure 7 (a), 7 (b). Measuring the Volume of Objects with the Disc Method Approach

Activity 4. Connecting Measurement Results with Mathematical Formulas

Tactile media exploration activities have helped students understand the basic concept of integrals. At this stage, students understand the usefulness of integrals in everyday life, namely, by using real objects directly.

The lecturer then presents a problem that is solved using a mathematical formula. The problem concerns calculating the surface area and volume of a rotating object. The mathematical formula used to calculate the surface area is $L = \int_b^a f(x)dx$. The mathematical formula used to calculate the volume of a rotating object is $V = \pi \int_b^a y^2 dx$. Students execute the problem using integrals and various mathematical symbols at this stage.

Students can easily calculate using mathematical formulas. This is because they have understood the integral formula and the calculation of integral problems. However, some students still have difficulty with fractional operations. Students can use mathematical formulas, but the final answer is wrong because the calculation procedure is not careful.

Activity 5. Interpretation of Abstract Concepts Using 3D Visual Media

The students then carried out mathematical abstraction activities using visual media, namely Geogebra. Learning is currently developing due to technological developments. The 3D visual media used is a simulated graphic display using Geogebra.

The lecturer presented a problem regarding the surface area under the curve. The problem was solved using two different methods: the Riemann sum approach and the integral formula approach. The lecturer invited students to compare the measurement results using the Riemann sum and the integral formula$L = \int_b^a f(x)dx$. The calculation results were interpreted with Geogebra. The use of visual media with Geogebra helps students in mathematical abstraction activities.

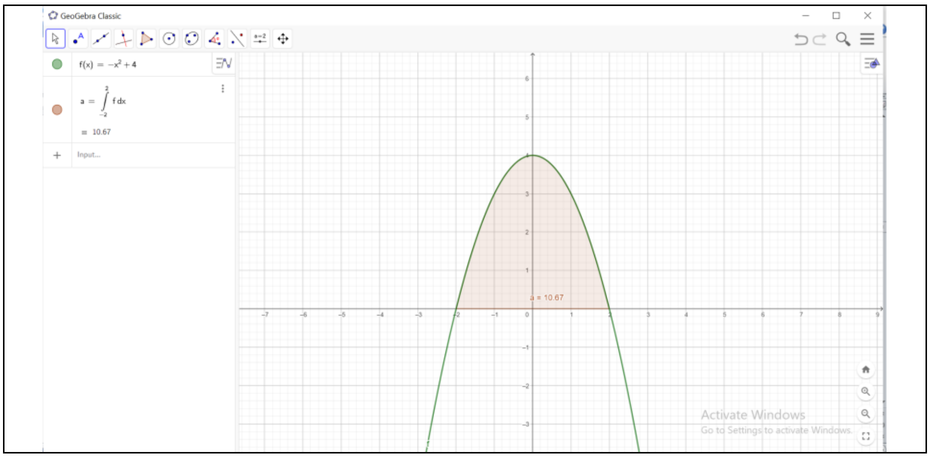

Figure 5. Visual Media Display with Geogebra

The students then carried out mathematical abstraction activities with the help of GeoGebra visual media. The lecturer presented a problem about the volume of a rotating object. The problem was solved using two different methods: the Riemann sum approach and the integral formula approach. The lecturer invited students to compare the measurement results using the Riemann sum and the integral formula$V = \pi \int_b^a y^2 dx$. The use of visual media with Geogebra helps students in mathematical abstraction activities.

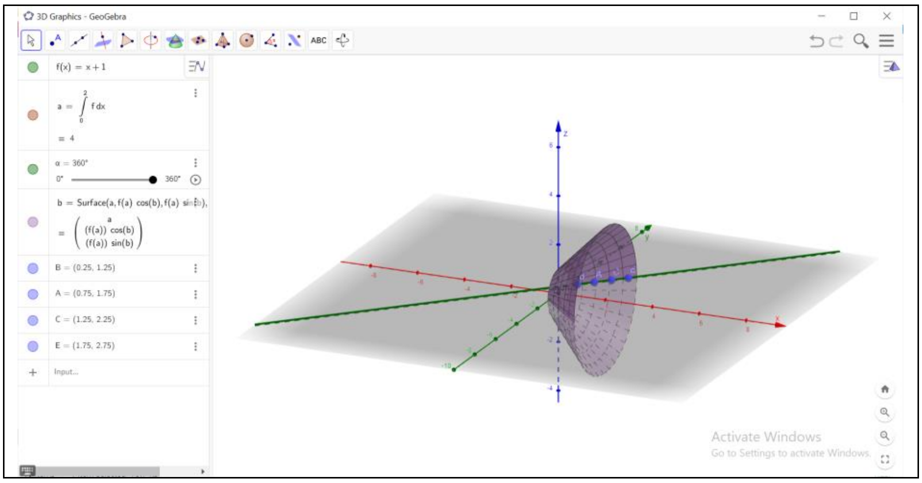

Figure 6. Use of 3D Visual Media with Geogebra

Activity 6. Stating Learning Experiences or New Things Obtained

At this stage, students are very enthusiastic in conveying their learning experiences. Students stated that they have become very familiar with using integrals in real life after learning. Initially, students admitted that they only understood integrals as formulas. Students stated that initially, they only had procedural knowledge, but after doing this learning, students have a conceptual understanding of integrals.

Students stated that the new skill they gained was calculating integrals directly using real objects. Previously, students only learned integrals through abstract example questions. The use of tactile media in this learning greatly helped students understand the use of integrals.

Figure 7. Students Express Learning Experiences or New Things Gained

Using 3D visual media in Geogebra helps students understand the concept of integrals abstractly, especially when calculating the volume of objects. Students can imagine how space is formed due to rotation on an axis.

Activity 7. Drawing Conclusions About Abstract Concepts

This stage is the final stage of learning. Students conclude the integral concept that they understand after going through a series of learning processes that have been carried out previously. The lecturer asks students to conclude what they understand about the integral concept. There are several opinions from students, namely: (1) integral is a concept for calculating the area and volume of objects, (2) the integral formula can be used when the function is known, as well as the upper and lower limits, (3) the Riemann sum and the disc method can be used both if the function is known or unknown, (4) the integral formula for calculating the area will produce almost the same results as using the Riemann sum. Likewise, the integral formula for calculating the area will produce almost the same results as the disc method.

The Effects of Mathematical Abstract Learning Using Tactile Media and Visual 3D Media to Student Mathematical Abstraction Skill

The effect of abstract mathematics learning using tactile media and 3D visual media on mathematical abstraction ability can be seen through the results of paired sample T-tests on pre-test and post-test values. The pre-test was conducted before the learning activity, while the post-test was conducted after the learning activity. The pre-test and post-test questions aim to measure students' mathematical abstraction ability.

The pre-test and post-test consist of two descriptive questions on integrals and measuring the surface area and volume of objects using integrals. The following are the descriptive test results of students' pre-test and post-test values.

Table 4. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Pre_Test	26	34	73	49.15	8.259
Post_Test	26	56	98	82.04	10.121
Valid N (listwise)	26				

Table 4 shows that the sample used was 26 students. The minimum pre-test score was 34, and the minimum post-test score was 56. The maximum pre-test score was 73, and the maximum post-test score was 98. The average pre-test score was 49.15, and the average post-test score was 82.04. Based on the minimum, maximum, and average scores, the post-test score is better than the pre-test score. The effect of abstract mathematics learning using tactile media and 3D visual media on mathematical abstraction ability can be seen through the results of the paired sample T-test. Before conducting a paired sample T-test, it is necessary to ensure that the pre-test and post-test scores are normally distributed. Data normality testing is carried out using the Kolmogorov-Smirnov test. The following are the results of the data normality test.

Table 5. Tests of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.
Pre_Test	.955	26	.300
Post_Test	.942	26	.151

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

There are two hypotheses in the data normality test$H_0 H_1$: TheH_0 means that the data is normally distributed, while $H_1$the data is not normally distributed. In Table 5, it can be observed that the Sig. The value for the pre-test is 0.300. This means that the Sig. Value> 0.05. ThisH_0 is accepted. This indicates that the pre-test data is normally distributed. In Table 2, it can also be observed that the Sig. The value for the post-test is 0.151. This means that the Sig. Value> 0.05. ThisH_0 is accepted. This indicates that the post-test data is normally distributed. Thus, the pre-test and post-test values are normally distributed, so a paired sample T-test can be carried out. The following are the results of the paired sample T-test.

Table 6. Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Post_Test - Pre_Test	32.885	9.279	1.820	29.137	36.633	18.070	25	.000

There are two hypotheses in the paired sample T-test$H_0 H_1$. Th$H_0$is means abstract mathematics learning using tactile and 3D visual media does not affect mathematical abstraction abilityH_1. In contrast, abstract mathematics learning using tactile and 3D visual media affects mathematical abstraction ability. In table 6, it can be seen that the Sig. (2-tailed) value = 0.000, so the Sig. Value <0.05. Thus, H_0it is rejected or H_1accepted. This states that abstract mathematics learning using tactile media and 3D visual media affects mathematical abstraction ability, which can be seen through the results of the paired sample T-test.

Table 7. Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre_Test & Post_Test	26	.506	.008

The strength of the influence can be seen in the correlation coefficient value, which is r = 0.506. This means a strong positive relationship exists between the pre-test and post-test values. Thus, there is a strong influence on abstract mathematics learning using tactile media and 3D visual media on students' mathematical abstraction abilities. The magnitude of the influence is obtained through the determination coefficient, which is$r^2 \times 100\% = (0{,}506)^2 \times 100\% = 25{,}6\%$. This means that abstract mathematics learning using tactile and 3D visual media contributes 25.6% to mathematical abstraction abilities, while other factors influence 74.4%.

Category of Student Mathematical Abstraction Skill

The mathematical abstraction ability of students after participating in abstract mathematics learning using tactile media and 3D visual media is as follows.

Table 8. Category of Student Mathematical Abstraction Skill

Category	Criteria		Total	Percentage
High	$X \geq \mu + 1\sigma$	$X \geq 92$	3	11,54%
Medium	$\mu - 1\sigma \leq X < \mu + 1\sigma$	$72 \leq X < 92$	20	76,92%
Low	$X < \mu - 1\sigma$	$X < 72$	3	11,54%

(μ =82,04 dan $\sigma = 10{,}121$)

In Table 8, it can be observed that 11.54% of students have high mathematical abstraction ability, 76.92% have moderate mathematical abstraction ability, and 11.54% have low mathematical abstraction ability. This indirectly explains that abstract mathematics learning using tactile media and 3D visual media positively impacts students' mathematical abstraction ability. This can be seen from the fact that only a few students have low mathematical abstraction ability.

DISCUSSION

Abstract mathematical concept learning is an important concern in mathematics education. This is because mathematics is a science that studies abstract objects. Nurrahmah et al. (2021) have previously studied (Nurrahmah et al., 2021)abstract learning. The study examined students' abstract thinking abilities from a mathematical disposition. Irawati et al. (2021) studied students' abstraction abilities in solving proof and refutation problems. Nurjannah and Kusnandi (2021) studied the role of abstract thinking abilities in strengthening students' prior knowledge in learning mathematics.

Several of the studies above examined students' abstraction abilities. This study explores how abstract mathematics learning activities use tactile and 3D visual media and how they affect students' mathematical abstraction abilities (Nuraisyah et al., 2021).

The abstract mathematics learning activities carried out were: (1) Reflection of the initial understanding of abstract concepts; (2) Orientation toward the use of abstract concepts in everyday life; (3) Measuring the surface area and volume of objects using tactile media; (4) Connecting measurement results with mathematical formulas; (5) Interpreting abstract concepts using 3D visual media; (6) Expressing learning experiences or new things obtained; (7) Concluding abstract concepts. These activities contain mathematical abstraction activities ranging from reflective, empirical, and theoretical abstraction.

In the learning activities above, students show active participation. This is because they explore directly with real objects to solve integral problems. Students also show reflective, empirical, and theoretical abstract thinking activities. Reflective abstraction activities include integrating formulas and problems and transforming problems into symbolic forms (Safitri, 2024b, 2024a; Safitri, Lestarani, et al., 2024; Safitri, Rosnawati, et al., 2024; Safitri & Ansyari, 2024). Empirical abstraction consists of generalizing, forming mathematical concepts with other concepts, forming advanced mathematical objects, and formalizing mathematical objects. Theoretical abstraction involves processing symbol manipulation (Irawati et al., 2021).

The learning carried out used tactile media and visual 3D media. Tactile media in mathematics is used to help students explore mathematics by themselves through direct interaction with physical objects (Yackel, 2016). Tactile media in mathematics learning has been widely used in various branches of mathematics, such as fundamental, differential, and integral (Barnes & Libertini, 2018). Visual media greatly helps students understand illustrations of an abstract problem. This aligns with Boaler et al. (2016), who state that visual media is needed to shape students to think abstractly. Learning in the past only focused on words and numbers, but currently, most knowledge is displayed visually because it is rich in content and information (West, 2014). 3D visual media is also used to support tactile media.

Abstract mathematics learning using tactile and 3D visual media helps students understand abstract concepts so that they can understand the meaning and use of integrals in everyday life. The learning has a strong influence on students' mathematical abstraction abilities. Students can explain the concept of integrals correctly and can use the concept of integrals correctly to measure the surface area and volume of objects.

Students can also analyze graphs related to rotating objects' surface area and volume. Students can formulate problems in a mathematical form containing mathematical formulas and symbols.

Students who have abstraction skills have high-level knowledge. This knowledge consists of classifying and generalizing previous problems (Yilmaz, R., & Argun, 2018). Abstraction is a basic process of mathematics in the formation of mathematical concepts in students' minds by utilizing their previous knowledge (Adelia et al., 2020; Nurhasanah, F., Kusumah, Y. S., Sabandar & Suryadi, 2017). This abstraction begins with a deep constructivist process of previous knowledge, which is a source of forming new knowledge (Scheiner, T., & Pinto, 2016).

Students have a conceptual understanding of the concept of integrals. Conceptual understanding is needed to understand the formulas and meanings of what is being learned (Nussy, K. S., Laurens, T., & Ayal, 2022). Mathematical problems can be solved well if students understand the concept optimally (Valentine et al., 2024). Students must first understand the concept to determine the formula used to solve the problem. If students only memorize the formula, they will have difficulty solving mathematical problems in different contexts (Yanala, N. C., Uno, H. B., & Kaluku, 2021).

Learning conducted with tactile and 3D visual media has been proven to overcome students' problems understanding abstract mathematical concepts. Students show enthusiasm for learning using real objects to learn abstract mathematical concepts. Students stated that they have only studied integrals, such as formulas and calculations. With the presence of tactile and 3D visual media (Julianti et al., 2022), students now understand the uses of integrals in real life and better understand graphs related to objects' surface area and volume. This is expected to contribute to teaching other abstract concepts to make them easier for students to understand. Thus, mathematics can be a fun and easy lesson.

CONCLUSION

Abstract mathematics learning activities using tactile media and 3D visual media that have been carried out are: (1) reflection of the initial understanding of abstract concepts; (2) orientation towards the use of abstract concepts in everyday life; (3) measuring the surface area and volume of objects using tactile media; (4) connecting measurement results with mathematical formulas; (5) interpretation of abstract concepts using 3D visual media; (6) stating learning experiences or new things obtained; and (7) concluding abstract concepts. 2. Sig. Value. (2-tailed) = 0.000 <0.05, so abstract mathematics learning using tactile and 3D visual media influences mathematical abstraction abilities. The r value = 0.506 states that there is a strong influence on abstract mathematics learning using tactile media and 3D visual media on students' mathematical abstraction abilities. The magnitude of the influence is obtained through the coefficient of determination, which is 25.6%, which means that abstract mathematics learning using tactile media and 3D visual media contributes 25.6% to mathematical abstraction ability, while other factors influence 74.4%. So, 11.54% of students have high mathematical abstraction ability, 76.92% have moderate mathematical abstraction ability, and 11.54% have low mathematical abstraction ability.

This learning is expected to be followed up as one of the recommendations for learning activities for abstract mathematical concepts in the Mathematics Education Study Program. Further, researchers are expected to develop similar research to other variables. Similar learning can be done with technology-integrated learning media.

ACKNOWLEDGMENT

This work was supported by the students of the Mathematics Education Department of IAIN Ambon. The authors gratefully acknowledge the use of the department's services and facilities.

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