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Jurnal Inovasi Pendidikan IPA, 11 (1), 2025, 248-258

Fostering Creative Thinking and Creative Products through the STREAM Approach

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Received: 22 February 2024; Revised: 3 May 2024; Accepted: 10 October 2024

Abstrak: With the advancement of science and technology, teaching and learning practices should provide students with information acquisition skills to meet future science, technology, engineering, and mathematics (STEM)-driven labor needs. The integration of arts and religion in STEM education is approved as a primary force in fostering students' 21st-century skills. Creativity is the key component of 21st-century skills measured by creative thinking and product. There is a gap in understanding how integrating religion and arts into STEM study enhances students' creative thinking and creative products. The pre-experiment method is implemented with a one-group pre-test and post-test involving 12 semester four students of the Primary Education Teacher Training Program, University of Nahdlatul Ulama Indonesia. This research implements two instruments: (1) creative thinking test items with fluency, flexibility, originality, elaboration, and evaluation aspects; (2) creative product scoring rubric in human movement system topic in creating robotic hand. The finding shows that the students' creative thinking enhanced quite significantly in all aspects. Specifically, flexibility and elaboration were the two highest creative thinking aspects, proved by a significant enhancement in those two aspects. Moreover, the result of the creative product revealed an average score of 82.44, which was categorized as good. All in all, lecturing with the STREAM approach in creating robotic hands can foster the creative thinking and creative products of the students.

Keywords: creative product, creative thinking, science learning, STREAM

How to Cite: Utami, A., Sandi, A. P., & Lutfa, A. (2025). Fostering Creative Thinking and Creative Products through the STREAM Approach. *Jurnal Inovasi Pendidikan IPA*, *11*(1), 248-258. doi:https://doi.org/10.21831/jipi.v11i1.71527

INTRODUCTION

In this modern era, classroom activities are becoming more diversified as the integration of science and technology evolves in learning practices. Teaching and learning activities, for instance, should provide students with information acquisition skills to meet future STEM-driven labor needs. STEM education is widely approved to impact education, economics, and national prosperity significantly (Krajcik & Delen, 2016). The integration of science, technology, engineering, and mathematics (STEM) is the primary force in creating future economic stabilization (National Research Council, 2012). STEM education is closely related to the Sustainable Development Goals (SDGs) approved by the United Nations (López & Cabello, 2022), which has been internationally recognized as a significant factor that escalates the quality of education (Krajcik & Delen, 2016).

Following the development of science and technology, STEM education integrated arts and religion, which resulted in the integration of science, technology, religion, engineering, arts, and mathematics (STREAM) education. The A, which stands for *arts*, is the key component in fostering creativity when learning science (Rustaman et al., 2018). It is believed that arts could lead students to think out of the box resulting in innovation, which eases students' understanding of science concepts. As creativity is a multi-dimensional component, ideas may be unpredictable. However, several

challenges in the education sector in Indonesia revealed the need for teachers to focus on developing students' creative thinking abilities (Yani & Widiyatmoko, 2023) as the creativity of Indonesian students needs to be enhanced through several programs, specifically in the learning context (Sukardi et al., 2021).

According to the Islamic perspective, creativity shall follow the *tauhid* law and Islamic beliefs. The R in STREAM education, which stands for *religion*, can act as the guideline, reminder, and limitation that the primary goal of learning is to become a valuable and *akhlakul Karima ummat*. This issue is becoming essential, as seen from the 21st-century learning goal. The 21st-century teaching and learning aims to shape students' personalities (Zubaidah, 2019). This study focuses on the religious aspect according to Nahdlatul Ulama which follows the Ahlussunnah Wal Jama'ah An-Nahdliyah values namely *tawassuth (*moderate principle*), i'tidal (*maintenance of harmony*), amar ma'ruf nahi munkar (*enjoining right and forbidding wrong), *tawaazun (*rationale*),* and *tasamuh (*tolerant) (Hartini et al., 2021). These values may shape students' self-awareness, behavior, and attitude through educational practices that refer to religious values (Nur & Junaedi, 2021). The focus is to develop students' noble personalities and become valuable human beings for living and unliving things on earth (Widiyono, 2022).

STREAM education is believed to be the most suitable approach to fostering 21st-century skills (Agustina et al., 2022). Implementing the STREAM approach in a learning context follows several stages focusing on escalating students' cognitive and practical skills (Felder & Brent., 2024) through solving daily life problems or conducting projects following the stages of the engineering design process. The 21st-century skills are becoming an essential aspect mastered by both teachers and students, as it is known that academic comprehension means nothing if it is not followed by comprehension skills. Creativity is the key component of 21st-century thinking skills (Tang et al., 2020). Creative thinking is believed to be a multi-dimensional aspect that may lead students to create valuable ideas (Corazza & Agnoli, 2016). Like literacy and numeracy, creativity is also agreed as the essential outcome of schooling (Lucas et al., 2014). Fostering creativity in teaching and learning practices should be followed by the teacher's ability to create a social atmosphere that makes students feel secure to state ideas and take risks. Integrating the STREAM approach in the learning activities can trigger students to solve real-world problems, conduct innovative and creative thinking, understand science concepts, and create valuable products (Anindya & Wusqo, 2020). Several studies have been done to capture the creativity of pre-service teachers through the STEM approach. However, none of it measured the creative thinking and creative product of the university students through the STREAM approach, precisely following Ahlussunnah Wal Jama'ah An-Nahdliyah values. For instance, Agustina et al. (2022) researched university students' creative thinking through the STREAM approach (Agustina et al., 2022). Moreover, Corrigan, Panizzon & Smith (2021) researched how teachers could meet the demands of STEM, creativity and critical thinking when teaching (Corrigan et al., 2021). Furthermore, Haigh (2020) investigated fostering creativity through science education (Haigh, 2020). This research is precisely constructed to encourage creative thinking and creative products of the pre-service primary teachers in Universitas Nahdlatul Ulama Indonesia through the STREAM approach.

RESEARCH METHOD

The pre-experiment method is implemented with a one-group pre-test and post-test (Fraenkel & Wallen, 2012). This research aims to capture how the STREAM approach directly affects students' creative thinking and creative products by designing a robotic hand. The participants were asked to solve problems related to human movement systems with limited tools and materials to design a robotic hand. Their performance was captured during the process, while their creative thinking was measured through essay questions as the pre-test and post-test. The research was conducted at the University of Nahdlatul Ulama Indonesia. A sample of 12 students was established by using the total sampling method. The 12 students were semester 4 students of the Primary Teacher Training Program (*Pendidikan Guru Madrasah Ibtidaiyah)* enrolled in the science learning course in the academic year of 2021/2022.

Specifically, there are three stages of the research. Firstly, the preparation stage includes a literature study and a research plan. A literature study was conducted to identify the research problem and method, theoretical background, current research trends, research gap, research ideas, and innovation through synthetizing and deep analysis. Meanwhile, constructing the research plan includes

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

creating a research proposal and instrument, conducting the preliminary survey, and preparing a research strategy.

Secondly, the implementation stage (fieldwork) was divided into three phases. The first phase was delivering the pre-test to capture students' creative thinking. Moreover, the STREAM approach explicitly teaches about the human movement system and force. In the second phase, students were asked to create the mechanism of the robotic hand, which would ease their understanding of the concept. Moreover, the student's robotic hand product is also assessed using a creative product rubric following the Creative Product Analysis Matrix (CPAM) (Besemer & Treffinger, 1981). The third phase delivers a post-test to capture how the STREAM approach could affect creative thinking. The research design of the implementation process is presented in Figure 1 below.

Figure 1. Research Design

Thirdly, the analysis stage, where data were collected and observed through descriptive statistics. The data were tabulated into tables and graphs and analyzed descriptively. Creative thinking was interpreted according to five aspects: fluency, flexibility, originality, elaboration, and evaluation (Rustaman et al., 2018). Meanwhile, the creative product was analyzed according to the novelty, resolution, elaboration, and synthesis aspects (Besemer & Treffinger, 1981). The STREAM approach is constructed following the National Research Council (Bybee, 2015) and the value of *Ahlussunnah Wal Jama'ah An-Nahdliyah*.

This research used two instruments: (1) creative thinking test items with the STREAM approach and (2) creative product scoring rubric. The instruments were validated through expert validation and Pearson's Product Moment. There were three expert validators, who were the senior lecturers of the University of Nahdlatul Ulama Indonesia. The empirical statistics validation was captured through Pearson's Product Moment, while the instrument's reliability was calculated using Cronbach's alpha. The test item's discrimination power and difficulty index were also measured (Arikunto, 2010).

Table 1. Creative Test Item Specification

Indicators	Creative Thinking Aspects				
	1*	2*	3*	4*	5*
Explain the mechanism of the human movement system according to scientific theory and how humans implemented the system to construct robotic hands and pieces of machinery.			√		
Calculate the perfect measurement of the robotic hand size and the length of its joints so that it uses effective force to move.	√				
Provide a solution to the problem of the mechanism of movement system. The answer should express one or more values of *tawassuth, i'tidal, amar ma'ruf nahi munkar, tawaazun,* and *tasamuh.*					√
Explain how technology and engineering concepts benefited the movement system.			√		
Explain how human movement system theory is implemented in constructing pieces of machinery.				√	
Analyze how science, technology, religion, engineering, arts, and mathematics concepts in human movement systems can innovate humans in creating machinery that makes life easier.		√			

Description: 1* Fluency; 2* Flexibility; 3* Originality; 4* Elaboration; 5* Evaluation

This research captures three different data sets analyzed using quantitative and qualitative methods. To determine the level of creativity, a quantitative analysis was performed using the difference between pre-test and post-test scores on creativity-focused assessments. Meanwhile, the qualitative data

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

were obtained from the creative thinking observation sheet and Creative Product Analysis Matrix (CPAM) (Besemer & Treffinger, 1981).

The quantitative data were analyzed by calculating the paired sample t-test and normalized gain (<g>) as follows:
Paired sample t-test:
$Var(A-B) = {\sigma_1}^{2+}{\sigma_2}^2 - 2\rho\sigma_1\sigma_2$

Where:
${\sigma_1}^2$ =variance of variable A
${\sigma_2}^2$ = variance of variable B
ρ = correlation coefficient for the two variables

$$t = \frac{\overline{X_1} - X_2}{\sqrt{\frac{s_1^2 + s_2^2 - 2\rho s_1 s_2}{n}}}$$

(Kim, 2015)

Normalized gain:

$$< g >= \frac{\%<G>}{\%<G>max} = \frac{(\%<S_f> - \%<S_i>)}{(100 - \%<S_i>)}$$

Description:
<g> = Normalized gain <G> = Actual gain
$<G>_{max}$ = Maximum gain possible $<S_f>$ = Average of post-test score
$<S_i>$ = Average of pre-test score

Table 2. The Description of the STREAM Approach

Aspect	Description
Science	Recognizing, offering, and evaluating explanations for a range of scientific phenomena.
Technology	Understanding technological principles by creating and using tools to solve the problem
Religion	Expressing the value of *tawassuth (*moderate principle*), i'tidal (*maintenance of harmony*), amar ma'ruf nahi munkar (*enjoining right and forbidding wrong*), tawaazun (*rationale*),* and *tasamuh (*tolerant)
Engineering	Designing the workflow of a robotic hand mechanism using scientific principles
Arts	Expressing innovation in creating a robotic hand with a beautiful and neat appearance and still following the scientific principles
Mathematics	Simplifying the situation to be amenable to mathematical analysis using measurable tools and materials

Table 3. Creative Thinking Aspects and Description

Aspect	Description
Fluency	Ability to provide several possible ideas, statements, suggestions, and answers to a problem
Flexibility	Ability to produce varied answers with different perspectives and points of view
Originality	Expressing original and unique ideas that others have never expressed and expressing unusual combinations of ordinary elements
Elaboration	Ability to develop, enrich, and simplify answers into understandable and detailed ideas
Evaluation	Determining the standard of self-assessment, the correct answer to a question, and wise action to face a situation

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Table 4. Creative Product Aspects and Description

Aspect	Description
Novelty	*Original* Being rare and out of the usual product that was ever made *Surprising* Giving surprise as a general first impression *Germinal* Triggering ideas for further original products
Resolution	*Valuable* Solving problems that are stated as project mission *Useful* Products can be used to provide benefits to everyday life
Elaboration and Synthesis	*Organist* Clearance of how the product is made *Elegant* The appearance of the product looks elegant and attractive, but the benefits are far more excellent than it seems. *Understandable* The user can clearly understand the materials and features of the product and their functions and should not confuse usage. *Artistic* Product neatness, effort in making product excellence, and daring to be different in product appearance

RESULT AND DISCUSSION

Creative Thinking

The result of students' creative thinking was captured through creativity test items in the form of six essay questions on human movement system topics. The instrument passed the validity and reliability test with the $r_{score} > r_{table} = 0.433$, showing that the instrument was valid to be implemented. In contrast, the reliability test was conducted through Cronbach's Alpha test with a score of 0.867 > 0.60, which means the instrument is reliable. The test item was delivered as a pretest and posttest, requiring students to think and construct creative answers. The pretest was administered at the beginning of the lecture. The lecture on the human movement system concept applied the STREAM approach. The students were given a project to create a robotic hand that implemented the concept of a human movement system. There were several conditions and limitations which should be followed. At the end of the lecture, the students did the posttest.

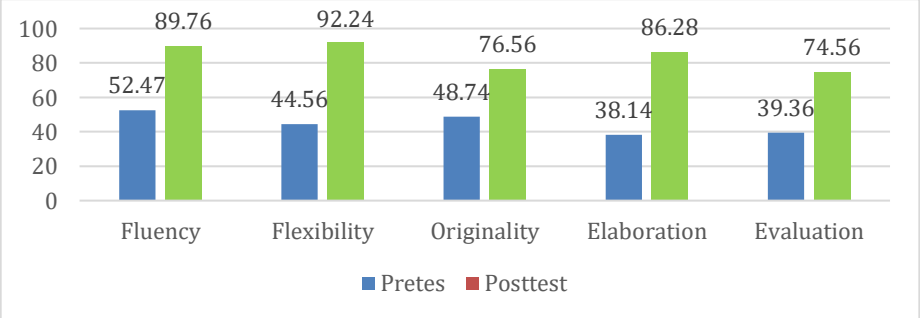

Figure 2. Creative Thinking Result

According to the result, the five aspects of students' creative thinking enhanced significantly after following the STREAM approach lectures on human movement systems and solving the project of creating a robotic hand. It can be seen from the chart that the highest score on the pretest was 52.47 in fluency, which means that at the initial stage, the student's ability to produce ideas, answer problems, and make statements is the highest compared to other aspects. The skill to think fluently is the ability to bring up varied statements, ideas, suggestions, and answers and solve a problem (Yayuk & As'ari, 2020).

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

On the other hand, the post-test results significantly enhanced the entire aspect of student's creative thinking. For instance, the flexibility aspect is at the highest score of 92,24, which means that students can produce varied ideas, answers, and solutions to a problem from different perspectives. The project to create a robotic hand with the STREAM approach is an essential aspect of enhancing students' ability to think fluently. This statement is supported by research by Yamin et al., which reveals that the project in science learning can trigger students' ability to think flexibly as the scientific project stimulates them to produce alternative ideas to solve the problem (Yamin et al., 2020). Additionally, the elaboration aspect reached a score of 86.28 in the post-test, which was enhanced from 28.14 in the pre-test. The enhancement is significant, meaning that students can enrich their skills and develop detailed ideas by exploring knowledge and skills. The essay question and student worksheet are found to guide students in constructing detailed workflow and answers to the questions (Sukmagati et al., 2020). Moreover, the post-test results on the originality and evaluation aspect show moderate results of 76.56 and 74.56, respectively. The originality aspect represents students' abilities to produce original ideas from imagination, which can be stimulated through habituation activities and projects (Gunawan et al., 2017) and STEM curriculum (Lou et al., 2017).

Moreover, to gain specific results of enhancing students' creative thinking, the researchers made simple statistical calculations to measure the average pretest and post-test scores and the normalized gain. The data show the average pre-test score is 44.65 and the average post-test score is 83.88. Following the calculation of normalized gain to capture the effectiveness of the STREAM approach in lecturing the human movement system to the result of student's creative thinking, the normalized gain score of 0.70 is categorized as a significant improvement. The result indicates that the STREAM lecturing approach and the project of creating a robotic hand enhanced the students' creative thinking.

Table 5. SPSS Paired Sample Test Result of Creative Thinking

	Mean	Std. Deviation	Std. Error Mean	95% Confidence interval				
				Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	-39.22600	8.67443	3.87932	-49.99673	-28.45527	-10.112	4	.001

The paired sample t-test was conducted through SPSS Version 24.0 to gain more specific data. The result of the paired sample test reveals that the sig. (2-tailed) is 0.001 < 0.05, which means that the H_0 is rejected and H_a is accepted. The result shows a significant difference in students' creative thinking before and after following the STREAM-approach lecture. It also supports the conclusion that the lecture on the human movement system following the STREAM approach can enhance students' creative thinking by creating a robotic hand.

All in all, students' creative thinking is enhanced significantly in all five aspects. This result follows the research that shows that students' creative thinking improved considerably after a STEM-based project in creating water filtration systems (Ridlo et al., 2020). Another study also reveals that projects on static fluid topics with a STEM approach enhance students' creative thinking (Saefullah et al., 2021). Not only creative thinking skills but also research on ethno-STEM project-based learning has also been found to impact students' critical thinking (Sumarni & Kadarwati, 2020). Moreover, research on 5th graders shows that the use of the STEM approach has been found to enhance students' creative thinking and science process skills (Lestari et al., 2018). The STEM approach can embed creative problem-solving techniques that can trigger the development of students' creativity and curiosity in science learning (Komis et al., 2017).

Creative Products

To measure the specific results of students' creativity after following the STREAM approach lectures on the human movement system topic, the researchers measured students' creative products. In this research, students conducted a project to create a robotic hand, which was then analyzed to determine students' creativity. According to the book entitled *Explaining Creativity: The Science of Human Innovation*, creativity is considered the interpersonal and intrapersonal process of the original, high-quality innovation of the process, product, or person (Sawyer, Robert Keith, 2024). The creative product is measured by the Creative Product Analysis Matrix (CPAM), which measures the three dimensions, namely novelty, resolution, and elaboration & synthesis.

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

Group 1 **Group 2** **Group 3**

Figure 2. The Robotic Hand Created by the Three Groups

Table 6. Creative Product Findings

Creativity Dimension	Indicator	Measured Aspects	Score (1-3)			Average	Percentage	Description
			Group 1	Group 2	Group 3			
Novelty	Original	Tools and Materials	2	2	2			
		product	2	3	1			
		Score	2	2.5	1.50	2.00	66.67	
	Surprising	Product	2	3	2	2.33	77.60	
	Germinal	Product	3	3	2	2.67	89.00	
	Average score		2.25	2.75	1.75	6.75	75.00	Fairly good
Resolution	Valuable	Product	3	3	3	3.00	100.00	
	Useful	Product	3	3	2	2.67	89.00	
	Average score		3	3	2.5	2.83	94.33	Very good
Elaboration & Synthesis	Organist	Product	3	2	3	2.67	89.00	
	Elegant	Product	2	2	2	2.00	66.67	
	Understandable	Product	2	3	3	2.67	89.00	
	Artistic	Product	2	3	1	2.00	66.67	
	Average score		2.25	2.50	2.25	2.33	77.67	Good
Total average			2.50	2.75	2.17	2.47	82.44	Good
Percentage (% per-group)			83.33 Good	91.67 Very Good	72.33 Fairly Good			

According to the result above, the overall result of the student's creative product reached a score of 82.44 and was classified as good (Arikunto, 2010). Research findings demonstrated that the project of creating a robotic hand implemented the STREAM approach, which significantly affected student creativity. This statement is supported by the research finding that STEM activities improved the student's STEM attitudes, scientific creativity, and motivation beliefs (Ugras, 2018). It is believed that students who enroll in STEM education are becoming creative individuals who can construct scientific solutions to problems and design creative projects (Yulianti et al., 2020).

Specifically, the novelty dimension reached a score of 75.00 categorized as fairly good. The novelty dimension is the lowest score compared to the other two dimensions. It might be because of students' lack of experience solving STREAM-based projects and creating robotic hands. It follows the statement that novelty is considered from the experience and prior knowledge of the creator (Acar et al., 2023). Moreover, originality, surprise, and germinability aspects are the three aspects of novelty, which point to the average score of 66.67; 77.60; and 89.00 respectively. The originality aspect is the lowest compared to another aspect as the expected result of the originality is producing a new, rare, and out-of-the-usual product ever created. Originality is the essential component of creativity (Acar et al., 2023). The originality score also correlates with the attitudes and values of creativity (Acar & Runco, 2019) stored in human cognition (Acar & Runco, 2014).

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

According to the result, the originality score is 2 for the three groups regarding tools and materials. İt is because the entire group used the same materials as presented by the lecturer at the beginning of the project. Moreover, it shows different results on the product aspect. The second group received the highest score as the product has its characteristics. Originality is scored according to the number of statistically new ideas (Agnoli et al., 2020). This factor is usually attributed to personal experience, prior knowledge, and cognitive level (Abdulla et al., 2020). İn the product aspect of originality, Groups 1 and 3 show the scores of 2 and 1, respectively. These two groups do not receive the highest score as the resulting product is common. Besides personal skill, originality can also depend on how students learn, as stated by Lucas et al., (2014) that meaningful learning is when students can explore their imagination. The second aspect of the novelty dimension is surprising. According to the result, the surprising aspect is that 77.60 is classified as good. Specifically, the 2nd group received the highest score of 3, followed by the 1st and 3rd groups which received a score of 2. Surprise is the unexpected design and product to an observer (Grace et al., 2015) directly related to the degree of creativity and human cognition (Weiss et al., 2021). The third novelty aspect is germinability, which shows the results of 89.00 classified as good. Germinability is the value that a product can trigger ideas for a further original product (Hanif et al., 2019) and open up new perspectives (Han et al., 2021).

Secondly, the resolution dimension resulted in an excellent result of 94.33, showing that the students are creating valuable and functional products that are logically constructed. The user can easily understand the concept and mechanism of operating the products. The robotic hand-built by the students can also work and solve the problem presented on the worksheet. This result follows the statement of Harvey & Berry (2023) that the resolution aspect measures the extent to which the product meets the needs of problematic situations (useful and functioning). There are two aspects of the resolution dimension, namely valuableness and usefulness aspects, pointing to the results of 100.00 and 89.00, respectively. Specifically, the three groups received the maximum score in the valuableness aspect, which shows that the products created by the students can be operated and attract people to use the products. Moreover, in terms of usefulness, the 3rd group received the lowest score of 2 as the robotic hand could not hold the weight for the longest time compared with the other two groups. The usefulness criteria measure how the product matches the practical performance (Hanif et al., 2019).

Thirdly, the elaboration and the synthesis aspect was categorized as good, with an average score of 77.67. The elaboration and synthesis dimension enables students to enhance their skills, knowledge, and ability to combine several elements into a complete unit carefully and in detail (Treffinger et al., 2021). The project is creating a robotic hand with the STREAM approach that facilitates students to construct elaboration thinking. STEM education can improve the elaboration thinking of students (Hasanah et al., 2019). The dimension of elaboration and synthesis has four aspects: organist, elegance, understandability, and artistic. According to the result, the organist and understandability aspect scored 89.00. In contrast, the elegant and artistic aspect pointed at only 66.67, which means that although the robotic hand can be used properly, the design of the product needs to be enhanced. The creativity value of a product is measured by how the product incorporates a novel situation of a problem.

CONCLUSION

The students' creative thinking enhanced significantly in the entire five aspects after creating robotic hand with the STREAM approach. It can be seen clearly from the answer to the student's worksheet that 76.56% of the students can explain how technology and engineering concepts benefited the mechanism of the human movement system. Moreover, 89.76% of the students were able to create the perfect ratio of hand size, joints, and fingers of the robotic hand, resulting in the effective force to move. Following that, 74.56% of the students can solve the problem of movement system mechanism by expressing the values of *tawassuth, i'tidal, amar ma'ruf nahi munkar, tawaazun*, and *tasamuh*. The 86.28% can understand the constructing machinery based on their knowledge of creating robotic hands. Finally, 92.24% of students can produce varied ideas, answers, and solutions to the problems in designing a robotic hand. This is proven by the different types and varieties of robotic hands that students produce. On the other hand, the result of the creative product is classified as fairly good in the novelty aspect, very good in the resolution aspect, and good in the elaboration and synthesis aspect. All in all, the robotic hands created by the three groups are classified as good (82.44).

ISSN 2406-9205 (print), ISSN 2477-4820 (online)

ACKNOWLEDGMENT

The researchers offer their gratitude to Lembaga Penelitian dan Pengabdian Masyarakat Universitas Nahdlatul Ulama Indonesia for funding this research.

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