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Paper Circuit Project-based STEAM Learning to Enhance Student Understanding and Creativity

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ABSTRACT Students believed physics was one of the most challenging sciences in education, and their interest in learning physics was lacking. Therefore, this study aims to enhance students' understanding and creativity in the STEAM learning system on electricity by creating a project (Paper Circuit) using the students' creativity at the junior high school level—quantitative research with a pre-experimental design used for this study. The population is 8th grade and 9th grade (50 students adapted to the curriculum used in the school) in one of the Junior Secondary Schools located in Bandung and Cimahi, Indonesia. The data is obtained from the pretest-posttest results, which show that the average pre-test score was 57.04 and the post-test score was 76.64. The nonparametric test was tested using the Wilcoxon test to measure student understanding. The results from e Wilcoxon are .000, which shows sig. <0.05, which means there is a significant difference between pre-test and post-test. Students' creativity is obtained from the Creativity Product Analysis Matrix (CPAM), and the result for Project 1 is 73.71%, categorized as enough, and Project 2 is 83.13%, categorized as good. Based on the result, Paper Circuit STEAM project-based learning can enhance student understanding and creativity. STEAM project-based learning can be used as an alternative teaching strategy in junior secondary school.

Keywords: STEAM project-based learning, Students understanding, Students creativity, Electricity

1. INTRODUCTION

One of the STEM subjects that causes students difficulty understanding and confusion is electricity. Students believe physics is one of the most challenging sciences in education, contributing to their lack of enthusiasm and disinterest in learning (Yasin et al., 2018). This was also justified after the researchers conducted interviews with one of the schools in Bandung, grade 8 junior high school students, and grade 9 junior high school students in Cimahi. 37 of 45 students said that physics lessons were difficult to understand and that their interest in learning physics was lacking. In the interviews in grade 9 junior high school, they did not do an electricity experiment; there was no apparent reason why their teacher did not experiment on electricity, even though electricity is a challenge, according to Mulhall et al. (2001) in Journal (Yasin et al., 2018), since it contains exceedingly abstract and sophisticated concepts and is entirely dependent on models, analogies, and metaphors. Cao and Brizuela (2016) also stated that it is difficult for students to explain the role of the electric field in the interaction of the various elements of a circuit. There was also an alternative concept about electric current in the electric circuit that the students generated (Yasin et al., 2018). Anwari et al. (2015) stated that a STEM educational approach to learning about magnetism, electricity, and electrical energy could stimulate students' interest in science, provide deep and meaningful learning, and improve students' thinking and hands-on skills.

In Indonesia, there are still many teacher-centered learning-teaching processes. Students learn better when they engage in meaningful learning activities. The learning-teaching process still occurs through a direct knowledge transfer from teacher to student. Students learn better when they engage in meaningful learning activities. Project-based STEM learning is one of the alternative teaching strategies to encourage students to engage in meaningful learning (Hanif et al., 2019). STEM learning in many schools is heavily focused on science and mathematics

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while ignoring the critical role of engineering and technology (Christine & McDonald, 2016). In recent years, STEM has become a trending pedagogic topic in every education sector in many countries. In the United States, STEM has become a national priority, and the National Science Foundation has followed suit at all levels of secondary education (Sanders, 2009; Wannapiroon & Pimdee, 2022) to instill critical thinking skills in students so they have the potential to develop students become creative- thinking problem solvers who will ultimately thrive in the workforce (Wannapiroon & Pimdee, 2022; White, 2014). Implementing STEM into learning can help students improve their 21st-century skills (Farwati et al., 2021; Permanasari, 2016). However, in Indonesia, over the last six years, STEM implementation has primarily involved high school students, reaching 42%. Thus, strong encouragement is required to pique the interest of other education unit-level teachers in innovating by incorporating STEM into classroom learning (Farwati et al., 2021). Art has added an "A", and STEAM education now helps students better understand their world through diverse knowledge and perspectives conducive to cultivating their innovative abilities (Connor et al., 2015; Miller & Knezek, 2013).

Therefore, the researchers assume that Paper Circuit Project-based STEAM Learning will be proposed to solve students' problems with understanding and creativity in electrical concepts and applications. Project-based STEM learning is a methodology in which Science, Technology, Engineering, and Mathematics (STEM) are integrated into curriculum design. STEM project-based learning is distinguished by its design approach and multidisciplinary training. The project-based STEM learning design approach begins with creating a well-defined result by defining the purpose and organizing the project's summative evaluation. Students will next be assigned a task in which they must present their thoughts for solving a complicated problem in a novel way. Project-based STEM learning has the potential to boost creativity since students will build or enhance their product ideas. Creativity is a crucial talent that students should cultivate (Dawes & Wegerif, 2004; Hanif et al., 2019). Creativity is creating a novel and appropriate response, product, or solution to an open-ended task (Amabile, 2012). If creativity is related to study and technology, it will result in high-quality work. STEM project-based learning has assessed students' creativity in adventure, curiosity, imagination, and challenge (Hanif et al., 2019).

STEAM education is a learning management extension of STEM education designed to integrate four subjects: science, technology, engineering, and mathematics. The STEAM model of learning management encourages student innovation and design thinking, providing possible solutions. Real problems due to the engineering design process. Below are process-based teaching and learning models for structural design: (1) Problem identification, (2) Finding relevant information, (3) Solution design, (4) Planning and development, (5) Testing and evaluation and design improvement, (6) Presentation. Art integration under the STEAM concept is an innovative way to enable students to work through creative processes, experiential learning, real-world work practice, problem-solving, analysis, synthesis, evaluation, and creative skill development. Focused on design, resulting in improved cognitive skills, a better understanding of what is being taught, and the development of creative thinking (Wittayakhom & Piriyasurawong, 2020). Ogunleye (2018) stated that the word' integration' is the key to STEAM education. Bazler and Sickle (2017) stated that adding art to STEM increases students' systematic thinking skills, creativity development, and motivation enhancement.

Creativity is defined as novelty or originality; thus, it must generate something new and distinct. Something cannot be deemed innovative if it is inappropriate or unimaginative. As a result, teachers must be capable of cultivating pupils' creativity. According to Davies et al. (2013) in Journal (Aguilera & Ortiz-Revilla, 2021), if a teacher's teaching and instructional conduct promote the development of a student's creative potential, it must adhere to the following criteria: (1) grant freedom of use and displacement between spaces; (2) set aside sufficient time and avoid rushing into the development of the activities; (3) layout and incorporate a broad range of educational resources; (4) design novel and stimulating tasks; (5) focus learning from a perspective of play, minimizing pressures and permitting a structured yet flexible and self-directed learning experience; (6) promote cooperative work, dialogue, and respect; and (7) rely on the participation of external bodies and experts unconnected with the school (museums, research centers, etc.). The most significant part that has been addressed is how a teacher can enhance and provide action to students so they may have many creative ideas and new inventions in developing STEAM learning projects.

Many researches conducted on project-based STEAM learning, according to Taylor (2016) in this paper outlines reasons why integrating the arts with science, technology, engineering, and mathematics is not just another curriculum fad but an essential response to the pressing need to prepare young people with higher-order abilities to deal positively and productively with 21st century. Moreover, Purnamasari et al. (2020) have found that digital literacy for children based on steam in family education also plays a vital role in the program's success. In addition, Wandari et al. (2018) already describe that students' concept mastery and creativity in implementing project-based STEAM Learning in light and optic lessons are categorized as good. Furthermore, according to Sigit et al. (2022), the research results indicate that the Project-based STEAM learning model improves students' mastery of ecological concepts. The research has a limitation related to the assessment of students' attitudes. According to the journal, Rahmawati et al. (2021) describe project-based STEAM learning can train students' critical thinking skills in science learning through the electrical bell project.

Existing research in project-based learning has often focused on generic project implementations, neglecting the nuanced interplay between artistic expression, scientific principles, and interdisciplinary collaboration that characterizes STEAM education. Similarly, studies on STEAM education tend to lack in-depth investigation into specific projects, hindering a comprehensive understanding of their impact on student engagement, creativity, and cognitive development. Various research studies from Weibert et al. (2016) have investigated the implementation of project-based STEAM learning using paper circuits in elementary school and secondary school. The indicators used were not explained in detail to measure the increase in creativity, and students' understanding of electricity was not explained in more detail. In addition, Lindberg et al. (2020) researched improving students' creativity by using STEAM Project Learning for paper circuit projects with ethnographic methods in high school.

Furthermore, the research utilizing STEAM Project-Based Learning on student concept mastery and creativity skills through paper circuit projects was also conducted by Lee and Recker (2018). However, in this research, the participants are middle school students using pre-experimental research. The study aims to investigate how this hands-on, multidisciplinary approach enhances students' creativity and comprehension of electricity concepts. However, previous research did not explain the indicators used in more detail to measure the increase in creativity.

Therefore, the novelty in this research is that students' understanding was assessed using an objective test of cognitive levels C1 (remembering), C2 (understanding), C3 (applying), and 25 multiple-choice questions based on the Bloom Classification (Anderson & Krathwohl, 2001). To enhance students' creativity, the project was assessed using the instrument for creative product analysis matrix (CPAM) indicator. The teacher also assessed the results, and then it was seen whether students could increase their creativity or not. This research seeks to bridge this gap and unravel uncharted dimensions by examining how the synergy between the Paper Circuit Project, project-based learning, and STEAM education can redefine educational experiences.

The research problem would be stated as follows:

- How does the implementation of Paper Circuit after STEAM Learning in the Classroom?
- How does the improvement of Students' understanding after implementing STEAM Learning in electricity topic?
- How does the improvement of Students' Creativity after implementing STEAM Learning in electricity topic?

2. METHOD

2.1 Research Method

The quantitative method was used in this research. Quantitative research rigorously tests objective theories by analyzing the relationship between variables (Creswell & Creswell, 2018). Pre-experimental Design and Pre-test Post-test is chosen as the experimental research method. In pre-experimental designs, the researcher studies one group and implements an intervention during the experiment. This design does not have a control group to compare with the experimental group (Creswell & Creswell, 2018). The pre-experimental design was used to discover the effect of the STEAM Learning approach implemented by the researcher on students' STEAM Understanding and Creativity as seen in Table 1.

Table 1 Pre-experimental research design

Pre-test	Implementation	Post-test
Students' Understanding – Pre-test	Experiment Paper Circuit Project – implementation of STEAM learning	Students' Understanding – Posttest

Therefore, the researcher will know whether any change occurred due to implementing the STEAM Learning approach in learning electricity. Students' understanding was assessed using an objective test of cognitive levels C1 (remembering), C2 (understanding), C3 (applying), and 25 multiple-choice questions based on the Bloom Classification (Anderson & Krathwohl, 2001). All test assignments were analyzed by experts as part of the assessment and tested on the students. Test task results are used, modified, or deleted after evaluation. The objective test was analyzed using SPSS. The reliability score is 0.60, which is moderate reliability. Reliability is the constancy of stating that reliability refers to an understanding that the instruments used in research to obtain information can be trusted as a data collection tool and can reveal actual information in the field (Riskawati, 2018). The design of this research was a One-Group Pre-test Post-test Design. A pre-test was used to measure some understanding of participants in an experiment before receiving treatment. A post-test was used to measure some understanding of participants in an experiment after receiving treatment.

2.2 Participants

In this research, the sample is 8^{th}-grade and 9^{th}-grade students (adapted to the school's curriculum). One class (50 students) was a sample of this research implementing Project Base Learning through Paper Circuit Experiment. The location was at one of the schools in Bandung and Cimahi. The chosen school conducts the Merdeka and Cambridge curricula.

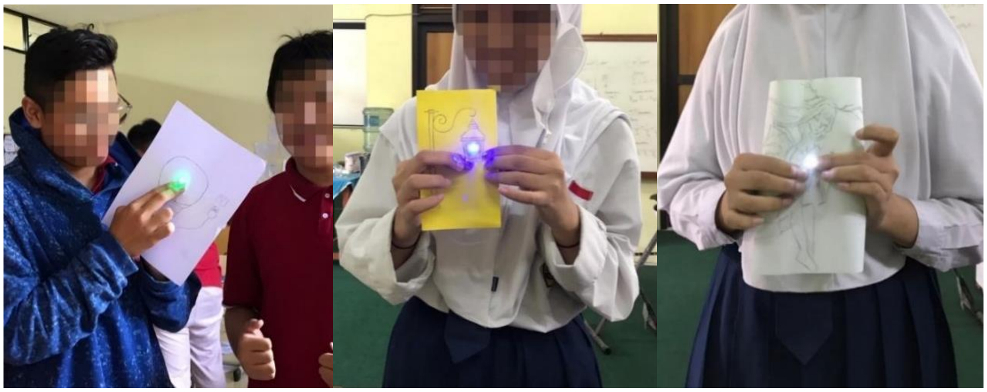


Figure 1 Students' paper circuit project (series circuit)

2.3 Research Instrument

A research instrument is required to collect the data. Several types of research instruments were used in this research. Those instruments are described as follows: The pre-test was given before conducting the treatment to determine students' STEAM understanding in basic electricity subjects. The worksheet was used to measure the creative implementation of STEAM learning in the class. The worksheet contains the steps students take, which will be assessed to determine whether students can do their projects. In the implementation, students create a Paper Circuit Project; in this observation, Project-based Learning is used to test students' STEAM Understanding and Creativity (Figure 1). A post-test was given after implementing the treatment to enhance STEAM understanding in basic Electricity subjects students. Table 2 shows the STEAM lesson plan.

Table 2 STEAM lesson plan

Meeting	Activity	Science Concept	Developed STEM
Meeting 1st	STEAM understanding and creativity Pre-test	- Electric Current - Resistance - Ohms' Law - Potential Difference - Series and parallel circuit	**Science** Students learn the basic principles of electricity, such as electric current, voltage, resistance, and power. **Technology** Students use technology in this project, including batteries, wires, and light sources like LEDs. **Engineering** Students learn the basic principles of electrical engineering and build more complex circuits. They will also apply engineering principles to solve problems in their project.
Meeting 2nd	Create Circuits Diagrams by using Paper Circuits (LED, Battery, and Cooper tape)		**Art** Students use art elements in this project, such as paper, scissors, and other decorative materials, to make their circuits look attractive and eye-catching. **Mathematics** Students can applyOhm's Law. Students will learn basic math about electrical principles, such as calculating voltage, current, resistance, and power.
Meeting 3rd	- Experimental: Series and parallel construction with PaperCircuits - Combined series andparallel construction - Making variation PaperCircuits Project. - Create a Circuit and Art	Electric Current: - Series and parallel circuit - Potential Difference - Resistance - Ohms' Law - Potential Difference - Electric Current - Resistance - Ohms' Law	**Science** Students learn how simple circuits work and how different materials affect the flow of electricity. Students can recall theprinciple of series and parallelcircuits. **Technology** Students use design software to plan and design their circuits. **Engineering** Students apply engineering principles to design and build circuits with the appropriate resistance. They will also troubleshoot and modify their circuits to achieve the desired results. **Mathematics** Students measure and record data to test their circuits.

Table 2 STEAM lesson plan (*Continued*)

Meeting	Activity	Science Concept	Developed STEM
Meeting 3rd	Design (drawing) Modifying the Circuit	- Potential Difference	
Meeting 4th	- STEAM Understanding Post-test		

Table 3 Instrument for creative product analysis matrix (CPAM)

Creative Dimension	Criterion	Score		
		1	2	3
		Lower	**Medium**	**Higher**
Novelty	Germinal	The product is inspiring others with the creation	The product is inspiring others to try something new	The product inspires others to try something new by directly giving ideas to develop more product design
	Original	Students primarily use the previous finding as their product idea	Students use the previous finding as their idea, but they modify the product	The product idea comes from their understanding
Resolution	Valuable	The product is incompatible with the purpose and does not relate to the concept.	The product is compatible with the purpose and does not relate to the concept.	The product is compatible with the purpose and relates to the concept.
	Useful	The product can be used once	The product can be used continuously with a specific requirement	The product can be used continuously without any requirement
Elaboration	Well Crafted	The product is done well	The product is done well with the good looking design	Students make an effort to give attractive product designs by using some material
	Expressive	The product is presented without body language and with a need to control the speaking tone, which is unintelligible.	The product is presented with a lack of body language and a need to control speaking tone, which is not understandable.	The product is presented communicatively (using effective body language and a clear voice) in an understandable manner.

(Hanif et al., 2019)

Besemer and Treffinger (1981) developed the creativity product analysis matrix (CPAM) for creativity for creativity. The data gathered from students' creativity is based on a creative product created by students as part of a STEAM project-based learning activity. Students' inventiveness is graded on a scale of 1 to 3 for each creativity criterion. The criterion employed is valuable, helpful, well-crafted, expressive, unique, and new. Table 3 shows the creativity product analysis matrix indicator.

2.4 Data Analysis

Using SPSS software, the pre-test and post-test outcomes in one class. Data analysis is broken down into numerous assessments to determine the understanding and creativity of electrical and circuit subjects. When assessing the data, the following statistical test was run.

Pre-requisite test

Pre-requisite tests are needed to determine which data will be processed into further tests.

The pre-requisite tests include the normality test and homogeneity tests.

Normality test

The normality test is carried out in order to test the distribution of data on a group or variable that is normally distributed or not. In this study, the results of the pre-test and post-test of the control class and experimental classes were tested using the Kolmogorov-Smirnov test. The following is the Kolmogorov-Smirnov formula:

$$D^{+} = \left\{\left(\frac{i}{n} - - zi\right)\right\}, 1 \le i \le n;$$

$$D^{-} = \left\{zi - \frac{i-1}{n}\right\}, 1 \le i \le n;$$

$$D = \max (D^{+}, D^{-});$$

$$D = D\left(\sqrt{n} + 0.12 + 0.11/\sqrt{n}\right)$$

Where,

zi = cumulative probability of s.n.d

Di = Difference between observed and expected values

D = Kolmogorov–Smirnov test statistic

n = population

(Yazici & Yolacan, 2007)

The analysis can be continued to the parametric test if the data is normally distributed. However, if data is not normally distributed, the data analysis is continued to the nonparametric test. The criteria for testing the Normality test using the SPSS program are as follows:

- If the significance value is < 0.05, then the data is not normal
- If the significance value is > 0.05, then the data is normal

Homogeneity test

A homogeneity test was carried out to determine whether samples from the control and experimental classes came from uniform populations. The test used in the study is the Levene test because the data is a scale. The criteria for testing the Homogeneity test using the SPSS program are as follows:

- If the significance value is >0.05, then the data is not homogeneous
- If the significance value is < 0.05, then the data is homogeneous

2.5 Hypothesis

H.0 There is no significant difference in students' understanding and creativity between before implementation and after implementation of electricity material and made paper circuit project in STEAM learning.

Ha. There is a significant difference in students' understanding and creativity before and after the implementation of electricity material and paper circuit projects in STEAM learning.

The hypothesis will be measured with the Wilcoxon test. Wilcoxon test using the SPSS program are as follows:

- If the significance value is < 0.05, then the data is a significant difference between the pre-test and post-test
- If the significance value is > 0.05, then the data is no significant difference between the pre-test and post-test

3. RESULT AND DISCUSSION

3.1 Implementation of Paper Circuit after STEAM Learning in Classroom

To investigate the implementation of the project in this lesson, students will explore the basics of electricity through hands-on STEAM activities. Students will work in teams to design, build, and test circuits and investigate the properties of different materials to understand how they affect the flow of electricity. They will also learn about the history and importance of electricity in our daily lives and the role of electrical engineers in developing new technologies. Table 4 shows the learning activity plan.

In meeting 1, students fill out the pre-test provided within 30 minutes before the lesson starts to determine

Table 4 STEAM learning lesson plan

Meeting	Activity	Science Concept	Implementation	Developed STEAM
Meeting 1st	STEAM understanding and creativity Pre-test	Electric Current Resistance Ohms' Law Potential Difference Series and parallel circuit	100%	**Science:** Students learn the basic principles of electricity, such as electric current, voltage, resistance, and power. **Technology:** Students use technology in this project, including batteries, wires, and light sources like LEDs. **Engineering:** Students learn the basic principles of electrical engineering and build more complex circuits. They will also apply engineering principles to solve problems in their project.
Meeting 2nd	Create Circuits Diagrams by using Paper Circuits (LED, Battery, and Cooper tape)		100%	**Art:** Students use art elements in this project, such as paper, scissors, and other decorative materials, to make their circuits look attractive and eye-catching. **Mathematics:** Students can apply Ohm's Law. Students will learn basic math about electrical principles, such as calculating voltage, current, resistance, and power. **Experimental:** Series and parallel construction with Paper Circuits Combined series and parallel construction
Meeting 3rd	Making variation Paper Circuits Project.	Electric Current: - Series and parallel circuit Potential Difference Resistance Ohms' Law Potential Difference	100%	Making variation Paper Circuits Project. Create a Circuit and Art Design (drawing) Modifying the Circuit **Science:** Students learn how simple circuits work and how different materials affect the flow of electricity; Students can recall the principle of series and parallel circuits.
Meeting 4th	STEAM Understanding Post-test	Electric Current Resistance Ohms' Law Potential Difference	100 %	**Technology:** Students use design software to plan and design their circuits. **Engineering:** Students apply engineering principles to design and build circuits with the appropriate resistance. They will also troubleshoot and modify their circuits to achieve the desired results. **Mathematics:** Students measure and record data to test their circuits.

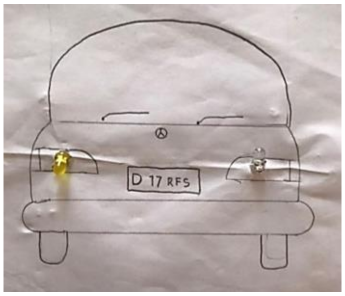


Figure 2 The art

Figure 3 The circuit (series)

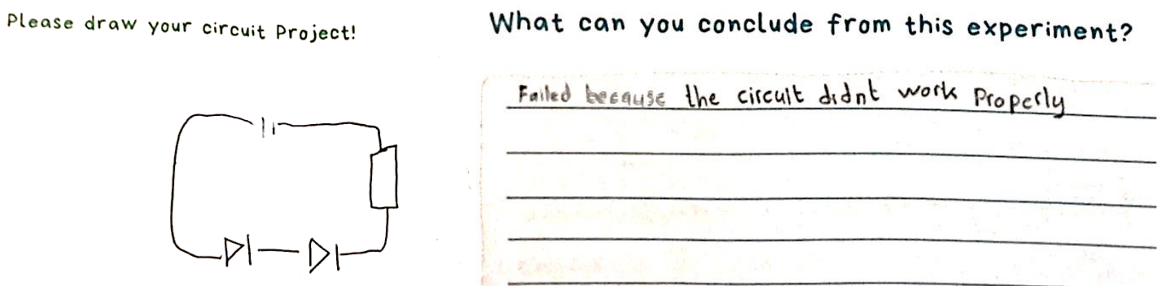


Figure 4 The student's answer in the worksheet after making Car Paper Circuit

their understanding of electricity before being given the actual material. The 30 questions are in the form of multiple choice, which includes Science, Technology, Engineering, Mathematics, and Creativity. After completing the pre-test, students are given material about Electricity (Electric Current, Resistance, Ohms' Law, Potential Difference).

In meeting 2, before students do experiments, students are first given material about electricity (continuing material from meeting 1); after the teacher delivers the material, it is continued by students doing experiments. In groups, students can arrange projects very well and then draw art on paper creatively with the combination of LED, Copper tape, and art they make. In this project, all the students made a series circuit and used 1 LED, but their art in the paper was very diverse. No obstacles were found, and the projects made by students were all successful. Students can also describe the circuit they made.

In meeting 3, the treatment given to students was the same as in meeting 2, but at this meeting, students were required to do a different project than before to see if there was an increase in the creativity of these students. Students draw art that requires them to use more than 1 LED light. After they do the project, continue to fill in the worksheet that has been provided. At this meeting, several obstacles were found in the project's making. After the students assembled the paper circuit, a group experienced that the LED lights did not light up at all; the result in Figure 2.

After making the project above, students fill out the worksheet that has been provided. The following is an explanation from students after working on a paper circuit project as shown in Figure 3.

From Figure 4, the average student answered that because the circuit they made was not optimal (there was damage), the copper tape did not stick too much to the paper, so the current from the battery could not flow optimally. The LED lights could not turn on—students who string electricity in series experience cases like this.

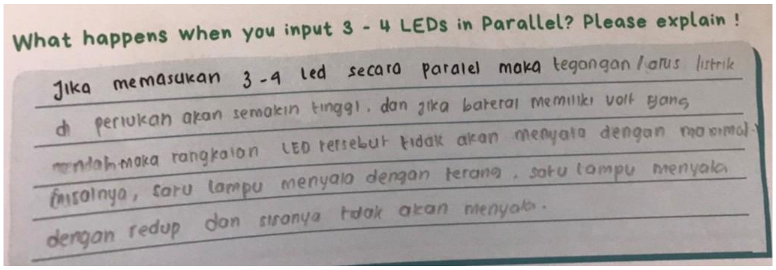
Students who string electricity in parallel also have problems; the LEDs cannot all light up (only 1 or 2 LEDs can light up). They are also required to find out the problem. The worksheet answers why the project that was carried out was successful or did not go well. This has been answered for the group that made the circuit in series

Figure 5 The art (traffic light)

Figure 6 The circuit of Traffic Light (Parallel)

Figure 7 The art (Birthday Cake)

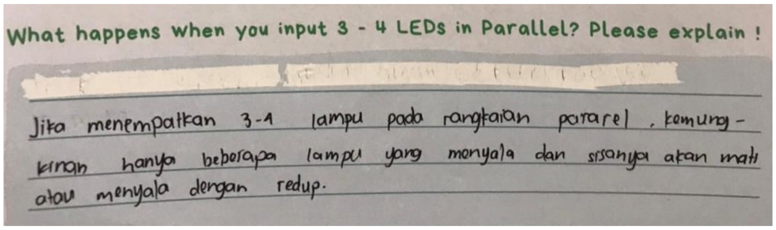
Figure 8 The circuit of Birthday Cake (Parallel)



What happens when you input 3 - 4 LEDs in Parallel? Please explain !

Jika memasukan 3-4 led secara paralel maka tegangan / arus listrik di perlukan akan semakin tinggi . dan jika baterai memiliki volt yang rendah maka rangkaian LED tersebut tidak akan menyala dengan maximal misalnya, satu lampu menyala dengan terang , satu lampu menyala dengan redup dan sisanya tidak akan menyala .

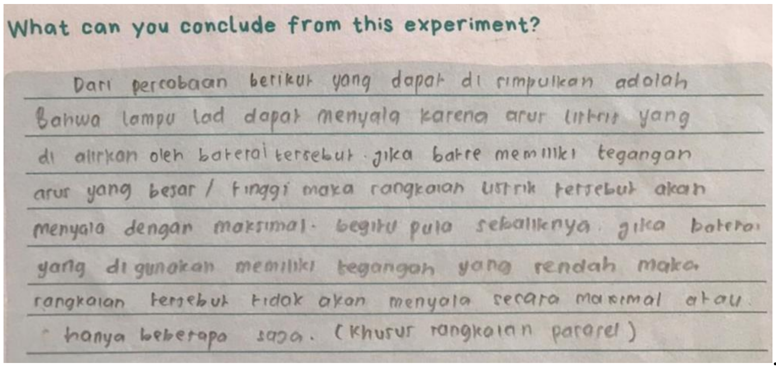
If you insert 3-4 LEDs in parallel, the required voltage will be higher, and if the battery has a low voltage, the LED circuit will not light up optimally. For example, one light is on brightly, one dimly, and the rest are off.



What happens when you input 3 - 4 LEDs in Parallel? Please explain !

Jika menempatkan 3-4 lampu pada rangkaian pararel , kemungkinan hanya beberapa lampu yang menyala dan sisanya akan mati atau menyala dengan redup.

If you place 3-4 lights in a parallel circuit, chances are only a few will be lit, and the rest will be off or dim



What can you conclude from this experiment?

Dari percobaan berikut yang dapat di simpulkan adalah bahwa lampu led dapat menyala karena arus listrik yang di alirkan oleh baterai tersebut . jika batre memiliki tegangan arus yang besar / tinggi maka rangkaian listrik tersebut akan menyala dengan maksimal . begitu pula sebaliknya jika baterai yang di gunakan memiliki tegangan yang rendah maka rangkaian tersebut tidak akan menyala secara maximal atau hanya beberapa saja . (Khusus rangkaian pararel)

The experiment concludes that LEDs can light up because of the electric current from the battery. If the battery has a large voltage, the electrical circuit will run at maximum, turning on the LED, and vice versa. If the battery has a low voltage, the circuit will not turn on the LED optimally.

Figure 9 Student's answer from their worksheet

because the series circuit is one branch, so if one lamp is damaged, all of them will turn off. Unlike the parallel circuit, some students make a traffic light project. They use 3 LEDs and one 3V battery, and only 2 LEDs are lit; this proves that the electric power from the battery is not strong enough to turn on 3 LEDs and only able to turn on 2 LEDs (Figures 5-9).

After making the project above, students fill out the worksheet that has been provided (Figure 9). The following is an explanation from students after working on a paper circuit project.

Paper Circuit includes PBL in STEM Learning. PBL is based on constructivist concepts, learning through authentic, specific contexts and involving the students in their learning (Kokotsaki et al., 2016). Alternative methods enhance student engagement in actual problem-solving, allowing for applying multidisciplinary concepts and processes and increasing knowledge generalization and enthusiasm toward these fields (Asghar et al., 2012).

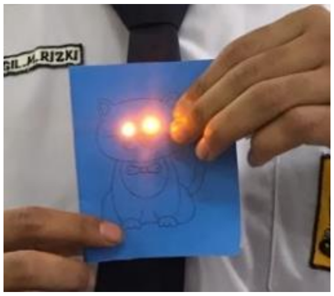


Figure 10 Make a cat

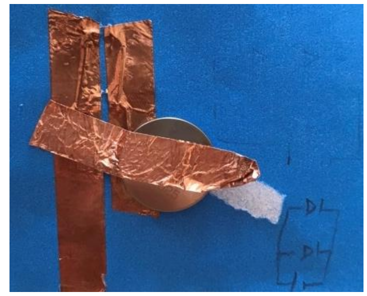


Figure 11 Parallel circuit from a cat

Furthermore, PBL can improve students' understanding and creativity while creating a project. It can be seen from the results of the project and the answers they gave in the student worksheets. From the answers above, they are already beginning to understand why the student's LEDs cannot turn on or not all the LEDs can light up from here. The testers think the students already understand more about electricity and can make projects skillfully and creatively. On the other hand, other students who make parallel circuit projects using 2 LEDs can run well; the lights can glow brightly. It looks like Figures 10-11 students who make parallel circuits using 2 LEDs.

In meeting 4, students are given the last material about electricity and the conclusions of all of the meetings starting from meeting 1 to the last meeting (meeting 4). After being given this treatment, students must complete the Post-test to determine whether there is an enhancement in their understanding of electricity. 30 Post-test questions must be done in 30 minutes and are presented in the form of a G-form so that students can fill them out from their respective devices.

3.2 Improvement of Students' understanding of Electricity after STEAM Learning

To measure students' understanding of electricity, the researcher conducted a pre-test and post-test on the sample (students). Students work on 25 questions about electricity in 30 minutes. The pre-test is given at the first meeting before students receive treatment material from the researcher, and the post-test is given at the last meeting (meeting 4) after the researcher gives the material about electricity.

Using SPSS software, the outcomes of the pre-test and post-test in the control class and experimental class will be examined. Data analysis is broken down into numerous assessments to determine the understanding. To see the effect of Paper Circuit Project-based STEAM Learning to Enhance Student Understanding of concepts pre-test and post-tests to see students' initial abilities, students' final abilities, and improvements the student. Calculating the normalized gains gives us a deeper understanding of the student's concepts.

Data normality was checked as a basis for choosing an appropriate statistical method and the result of the normality test using SPSS. There are two types of calculations: Kolmogorov-Smirnov and Safiro-Wilk. The first type is used when there is a large amount of data (>50), and the second type is used for small data. As seen from Table 5, the pre-test and post-test score distribution is abnormal (sig.<0.05).

A homogeneity test was conducted to determine whether samples from one class came from uniform populations. The test used in the study is the Levene test. The score is .490; the data is not homogeneous because the significance value is >0.05. If the significance value is < 0.05, then the data is homogeneous.

In this research, the scores of sig. in the pre-test and post-test are not normal (sig.<0.05). Then, the data analysis continued with the nonparametric test (Hake, 1999).The nonparametric test was tested using the Wilcoxon test. The results from the Wilcoxon are .000. The basis for the decision of the Wilcoxon test is the value of asymp. Sig> 0.05, then there is no difference, but if the asymp. Sig value <0.05, then there is a significant difference. The results of the data obtained and tested using SPSS show sig. <0.05 means there is a significant difference between the pre-test and post-test results. Statistical data and the result of students' improved understanding scores in electricity are shown in Table 5.

Table 5 Descriptive statistical data of students' improvement understanding score in electricity

Statistics	**Value**	
	Pre-test	**Post-test**
Mean	57.04	76.64
Variance	160.529	190.276
Minimum	20.00	36.00
Maximum	88.00	100.00
Standard deviation	12.67	13.79
Median	60.00	76.00
Normality Test (Kolmogorov-Smirnov - Sig.)	.000 (not normal)	.039 (not normal)
N-Gain	0.43	(medium)
Homogeneity (Levene test Sig.)	.490	(not homogeneous)
Willcoxon test (Asymp. Sig.)	.000	(significant difference)

Table 5 shows a difference between pre-test and post-test results, and the N-gain values demonstrate the effect of Paper Circuit Project-based STEAM Learning to Enhance Student Understanding of Concepts. Students' average improvement gain score in conceptual understanding was 19.60, increasing from 57.04 to 76.64. Based on the calculation, the N-Gain is 0.43, which is categorized as medium (Meltzer, 2002).

As presented in Table 6, the data indicates achieved at every level of cognition. Notable improvements from the pre-test to the post-test were observed in all cognitive levels: C1 showed a gain of 19.5, C2 showed a gain of 15, and C3 demonstrated a gain of 26. The questions on the test items are mainly on the C2 indicator; the N-gain is in the low category; this shows that the difference between the pre-test and the post-test is small and not too significant; many students can answer the questions about the C2 indicator before implementation so that after carrying out the implementation post-test on C2 it did not increase significantly. In C1, many students forget the theory because there are many types of C1 questions that are recalling and remembering, so when they are reminded again at the second meeting and implementation, students can answer C1 questions well, therefore the C1 indicator is medium, which indicates that there is an increase from pre-test to post-test. However, a significant difference can be observed in C3. In the pre-test, students were confused about finding the amount of resistance/voltage/current in a problem using the $V = I \times R$ formula before explaining the theory of Ohm's law. After being given an explanation of the theory and implementation, most students could answer question C3 correctly; this caused the C3 results to be more significant than C2. The test item in C3 only has two questions, perhaps distinguishing a significant increase between C1 and C2. On the other hand, it can also be concluded from the gains that have been obtained that there has been a significant increase in students' understanding after implementing project-based STEAM learning in class.

Table 6 Recapitulation of students' understanding objective test item in each cognitive level

Component	Key Components		
	C1	C2	C3
Pre-test	56.83	61	52
Post-test	76.33	76	78
Gain	19.5	15	26
N-gain	0.51	0.23	0.53
N-gain category	Medium	Low	Medium

This result is supported by previous findings (Wandari et al., 2018). STEAM-based learning can improve students' understanding, and previous findings by (Kim et al., 2014) show that STEAM education has been proven to benefit academic achievement. This learning experience can open up exciting possibilities for students (Wandari et al., 2018).

Another research study (Henriksen, 2014) showed that STEAM education has significantly impacted academic achievement, basic scientific process skills, and the affective domain. Integrating science, technology, engineering, arts, and mathematics in education has proven effective in enhancing learning outcomes and promoting a holistic approach to education (Table 7). Students exposed to STEAM education are better equipped with the skills they need to succeed in the modern world and are more likely to become successful and productive members of society. Kim et al. (2012) also stated in their research that the implementation of the STEAM Teaching Model results in enhanced student understanding of STEAM-related activities.

The previous research about Using Brain-Based Learning to Promote Students' Concept Mastery in Learning Electric Circuits from Sani et al. (2019) stated that Brain-Based Learning could be one of the alternative teaching approaches that can improve students' understanding of learning the electric circuit. Therefore, in this study, the researcher uses another way by using a paper circuit project-based STEAM learning as a medium to increase students' understanding. STEAM education used in this study is project-based learning and technology in the context of creativity and design (Aguilera & Ortiz-Revilla, 2021; Ozkan & Topsakal, 2019).

The increase occurred because, during the pre-test, there was no material given; after that, the teacher gave material in 4 meetings. After being given material and doing a project (implementation). In implementation, students did the discussion because when students made a project, has a problem. After implementation, the teacher gives

Table 7 The integration of STEAM in making paper circuit project

Science (S)	Technology (T)	Engineering (E)	Art (A)	Mathematics (M)
Current flow from the battery to LED. The principle of series and parallel circuits.	This project will use technology, including batteries, wires, and light sources such as LEDs.	Basic principles of electrical engineering and building more complex circuits.	Art elements in this project, such as paper, scissors, and other decorative materials, make their circuits look attractive and eye-catching.	Applying Ohm's Law, students will learn basic math related to electrical principles, such as calculating voltage, current, resistance, and power.

Table 8 Creative product analysis matrix (CPAM) rubric - Project 1

Creative Product Criteria	Criterion	Group 1			Group 2			Group 3			Group 4		
		1	2	3	1	2	3	1	2	3	1	2	3
Novelty	Germinal	√			√			√			√		
	Original	√			√			√			√		
Resolution	Valuable			√		√				√			√
	Useful		√		√			√			√		
Elaboration	Well Crafted	√			√				√		√		
	Expressive	√			√				√			√	
Creative Product Criteria	**Criterion**	**Group 5**			**Group 6**			**Group 7**			**Group 8**		
		1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Novelty	Germinal	√				√		√			√		
	Original	√				√		√			√		
Resolution	Valuable			√	√					√			√
	Useful	√				√		√			√		
Elaboration	Well Crafted		√			√			√			√	
	Expressive		√			√			√			√	

suggestions to the student, and in the last meeting after implementation, students are given a post-test to see if there is an increase in students' understanding of STEAM learning.

3.3 Improvement of Students' Creativity of Electricity after STEAM Learning

To find out the increase in student creativity in STEAM learning, students make 2 paper circuit projects. In this project, the students were divided into eight groups, each comprising 6-7 students. The project was completed at the second and third meetings. Students could do projects well at the second meeting without encountering problems, and the LEDs could light up properly. All students make a series of circuits, but their art for each group is different.

After the project was decided in the second meeting, Project 1 was assessed based on the CPAM indicators. The results from student projects are in Table 8.

The results were obtained based on the creativity rubric. Students' creativity is measured based on their product, which is making paper circuit projects (Hanif et al., 2019). 8 Groups' creativity is assessed by using the Creative Product Analysis Matrix (CPAM) adapted from Besemer and Treffinger (1981), shown in Table 8. Germinal and Original Criteria were chosen as the dimensions of novelty. The germination criteria are defined as products that are likely to offer additional creative product offerings in the future. In contrast, the unique criteria are how rare and rare a product with the same product idea bundled together indicates a similar experience. For the dimension of resolution, a useful and Valuable criterion was chosen. Criteria of value relate to how others judge a product to be of value because it satisfies an economic, physical, social, or psychological need; useful criteria are as follows: It has to do with how clear and practical the product is.

Moreover, the last, well-crafted and expressive criteria were selected for the elaboration dimension. Well-crafted criteria relate to how the product looks and has been edited or revised with the care that the ideas originate from, while

Table 9 Students' creativity results for each group

Group	Creativity Dimension (Project 1)			Average
	Novelty	Resolution	Elaboration	
1	70 %	78 %	75 %	74 %
2	68 %	60 %	50 %	59 %
3	70 %	75 %	80 %	73 %
4	75 %	78 %	80 %	77 %
5	70 %	78 %	83 %	76 %
6	70 %	78 %	78 %	75 %
7	75 %	80 %	80 %	78 %
8	75 %	75 %	80 %	76 %

strong criteria relate to how communicative the product is. These criteria define what should be presented intelligibly (Hanif et al., 2019).

All criteria for each creativity aspect are used to assess student project outcomes after conducting STEAM project-based learning. The recapitulation project 1 of students' creativity for each group is presented in Table 9.

Based on Table 9, the creativity performance of each group is different. Group 1 scored 74.33%, group 2 scored 59.33 %, group 3 73.33%, group 4 scored 77%, group 5 scored 76 %, group 6 scored 75.33 %, group 7 scored 78.33%, and group 8 scored 76 %. Based on the result, there is a distant gap in creativity between group 2 and the other group because group 2 has the lowest percentage of creativity, and the two groups that get the same average results, namely group 5 and group 8, get an average of 76 %.

Group 2 has the lowest percentage of creativity, which is 59.33%, categorized as low creativity (Hanif et al., 2019). Group 2 only makes the circuit (series circuit), not drawing the art like the other groups. Group 2 only used 1 LED and one resistor of 1 Ohm size. After testing, the LED does not turn on. As a result, group 2 did not make any effort to improve the quality of the product, in contrast to group 7, which got the highest score of 78.33%. Even though group 7 only used 1 LED, which was made in series, the art made by this group is very good, so this group can improve the

Figure 12 Result of Group 2 project

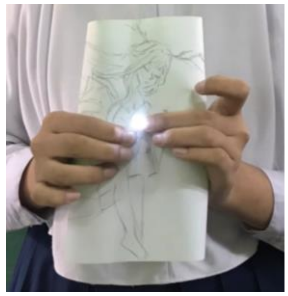


Figure 13 Result of Group 7 project

Figure 14 Group 2 - Project 1

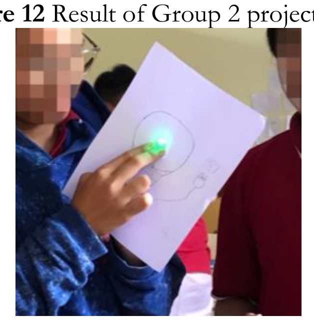


Figure 15 Group 2 - Project 2 (Lamp)

Figure 16 Group 4 – Project 1 (MONAS)

Figure 17 Group 4 – Project 2 (Traffic Light)

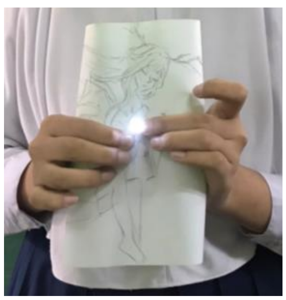


Figure 18 Group 7 – Project 1 (Tinkerbelle)

Figure 19 Group 7 – Project 2 (Birthday Cake)

Table 10. Students' creativity result

Creativity Dimension			Average	Category
Novelty	Resolution	Elaboration		
71.63 %	75.25 %	74.25 %	73.71 %	Enough

quality of the product. The product of Group 2 and Group 7 are shown in Figure 12 and Figure 13.

Figures 12 and 13 can compare the results of group 2 with group 7 and conclude why group 2 got the lowest score. However, from Table 8, the recapitulation of students' creativity in this study can be seen in Table 10.

Table 10 shows novelty scored 71.63%, resolution scored 75.25%, and elaboration scored 74.25%. The average score for each dimension of creativity after conducting STEAM project-based learning was 73.71%, which is categorized as enough based on Purwanto (2009). Students who made Project 1 of Paper Circuit through STEAM project-based learning had enough creativity.

At the third meeting, the students made a different circuit and drew art that was different from the previous project and required more than 1 LED. Project 2 was assessed based on the CPAM indicators. The results from student projects are in Table 11.

All criteria for each creativity aspect are used to assess student project outcomes after conducting STEAM project-based learning. Table 12 presents the recapitulation of Project 2 of students' creativity for each group.

Based on Table 12, the creativity performance of each group is different. Group 1 scored 80 %, group 2 scored 79.33 %, group 3 scored 81 %, group 4 scored 86 %, group 5 scored 82.67 %, group 6 scored 81.67 %, group 7 scored 87.67 %, and group 8 scored 86.67 %. Based on the results, there is no distant gap in creativity. Even though group 2 again has quite a gap with group 7. However, from Project 1, group 2 experienced an increase in creativity. Group 2 added art to their second project. Even though there is no art in Project 1, the creativity in arranging the electrical circuit can be seen in Project 1 because they used a resistor in the circuit; this makes the statement that the light cannot turn on because of the resistor and the battery power is not able to turn on the LED. In the second project, there is art (Lamp), but it is not enough to meet the assessment in the CPAM indicator because they only used 1 LED and one battery in the second project; it does not increase creativity in arranging electrical circuits, so this causes the value of group 2 to be smaller compared to other groups. The

Table 11 Creative product analysis matrix (CPAM) rubric - Project 2

Creative Product Criteria	Criterion	Group 1			Group 2			Group 3			Group 4		
		1	2	3	1	2	3	1	2	3	1	2	3
Novelty	Germinal		√			√				√	√		
	Original		√			√			√			√	
Resolution	Valuable			√			√			√			√
	Useful	√			√				√			√	
Elaboration	Well Crafted		√			√			√			√	
	Expressive		√			√			√			√	
Creative Product Criteria	**Criterion**	**Group 5**			**Group 6**			**Group 7**			**Group 8**		
		1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Novelty	Germinal	√				√			√			√	
	Original	√					√			√		√	
Resolution	Valuable			√			√			√			√
	Useful		√			√			√			√	
Elaboration	Well Crafted			√		√				√		√	
	Expressive		√			√			√			√	

Table 12 Students' creativity results for each group

Group	Creativity Dimension (Project 2)			Average
	Novelty	Resolution	Elaboration	
1	78 %	79 %	83 %	80 %
2	80 %	75 %	83 %	79 %
3	80 %	83 %	80 %	81 %
4	83 %	85 %	90 %	86 %
5	78 %	85 %	85 %	83 %
6	80 %	85 %	80 %	82 %
7	80 %	93 %	90 %	88 %
8	85 %	85 %	90 %	87 %

Table 13 Students' creativity result

Creativity Dimension			Average	Category
Novelty	Resolution	Elaboration		
80.50 %	83.75 %	85.13 %	83.13 %	Good

results of the progress of Group 2 and several other groups are in Figure 14 – Figure 19.

Figures 14- 19 show the results of Project 1 and Project 2. However, Table 11 recapitulates students' creativity in this study, as can Table 13.

Table 13 shows that novelty scored 80.50%, resolution scored 83.75%, and elaboration scored 85.13%. The average score for each dimension of creativity after conducting STEAM project-based learning was 83.13%, which is categorized as good based on Purwanto (2009). Students who made Project 2 of Paper Circuit through STEAM project-based learning had good creativity.

During the implementation phase, students conduct experiments to create their designed products. Furthermore, the experimental product is subjected to actual tests to ensure that it can work properly. Munandar (1999) stated that creative thinking skills can be developed through experiments and discussions between students (Hanif et al., 2019).

After creating the project, students must fill out the worksheet that has been provided. They also had to fill in several questions related to their project. From their answers, there are constraints on what they make. For example, in Figure 19, group 7 made a parallel circuit using three lights, but it turned out that one light was on one dim and the other one could not light up; it does not mean their product failed, from their worksheet answer is, because the voltage on the battery is weak so it cannot turn on 3 LEDs at once.

Group 2, who made a series circuit using 1 LED and one resistor in Project 1, stated that their project failed and could not work properly, as shown in Figure 14. Their reason is that there are obstacles in the circuit they made with copper tape, the voltage is not tremendous plus there is a resistor so that the electric current from the battery cannot turn on the lights. Another reason why group 2 did not draw the art, they said, was because they were busy repairing and finding solutions for how the LEDs should light up, so they did not think about drawing the art. However, in project 2, group 2 was able to create a project that was different from before; even though they still used 1 LED, they managed to make the project more creative by designing art on paper, so their project was more interesting than before, as shown in Figure 15.

In this case, the student's creativity is essential in developing practical solutions for repairing the student's product. Therefore, students should be able to create two different projects than before. From here, it can be seen whether students can improve their creativity in STEAM project-based learning in electricity or not. Figure 20 recapitulates students' creativity for each project.

Figure 20 shows an enhancement from Project 1 to Project 2 in each creativity dimension. Novelty in Project 1 shows a score of 71.63%, while Project 2 shows a score of 80.50%. The resolution on Project 1 showed a score of 75.25%, Project 2 scored 83.75%, and the last elaboration on Project 1 showed a score of 74.25%, while Project 2 scored 85.13%.

Tables 11 and 12 show that the average of Project One and Project Two has also increased. Table 10 shows Project 1 getting an average of 73.71%, which is categorized as

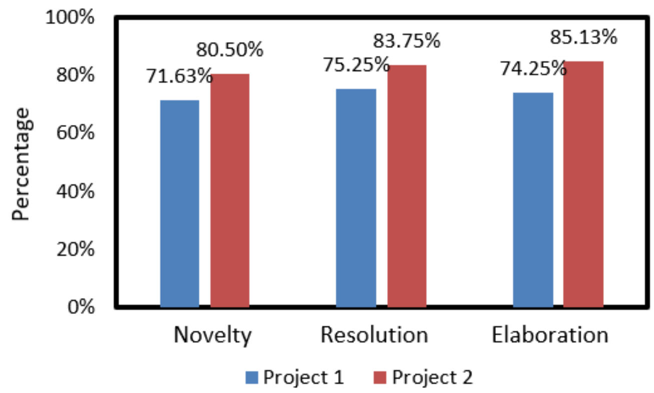


Figure 20 Students' creativity results from Project 1 until Project 2

enough; then, in Table 13, Project 2 gets an average of 83.13%, which is categorized as good. This shows an increase of 9.42%.

These results are supported by research conducted by (Kim et al., 2014) that showed a significant improvement in students' creativity using STEAM-based learning. (Kim et al., 2012) Research has found that STEAM leads to processes that result in creativity, innovation, and continued growth and exploration of the world. In another study conducted by (Lee & Recker, 2018), making a project with a paper circuit can help students develop productive thinking skills related to various important computational concepts.

This increase occurred after the teacher gave students more suggestions, and then students tried to make more exciting innovations than the projects they had previously designed. Previous research The Effect of STEAM-based Learning on Students' Concept Mastery and Creativity in Learning Light and Optics (Wandari et al., 2018) made a telescope and used CPSS to measure creativity in physics lessons (Light and Optics); in this research, students who implemented STEAM project-based learning in the concept of light and optics have good creativity in the dimensions of novelty, resolution, and elaboration and synthesis. The difference is that in this study after the students finish their project, the researcher gives a score with a CPSS rubric to the project done by the student and finds the average of the score, which is not significantly different. Based on research on STEAM education from the BERA Research Commissions (Colucci-Gray et al., 2017), which discussed examples of school science projects that successfully integrated art. However, it was noted that none of these projects were physics-based (Boyle, 2021). Therefore, this study used art to increase student creativity. Some scholars use the term "Arts" as a synonym for project-based learning, technology-based learning, or design-based learning (Perignat & Katz-Buonincontro, 2019), and in this research, STEAM education used project-based learning and technology in the context of creativity and design (Aguilera & Ortiz-Revilla, 2021; Ozkan & Topsakal, 2019). STEAM education strongly emphasizes the context in which the Engineering and Art process is developed. In contrast, STEM education tends to center more on the final products created by students (Aguilera & Ortiz-Revilla, 2021).

4. CONCLUSION

The study's findings indicate that the implementation of STEAM Learning has proven to be immensely successful, with each meeting yielding a 100% success rate. Table 5 shows that Students' average improvement gain score in conceptual understanding was 19.60, increasing from 57.04 to 76.64. Based on the calculation, the N-Gain is 0.43, which is categorized as medium (Meltzer, 2002). The score of sig. in the pre-test and post-test is not normal (sig.<0.05). Then, the data analysis is continued to the nonparametric test. The nonparametric test was tested using the Wilcoxon test; the results from the Wilcoxon is 000. which the results show sig. <0.05 means there is a significant difference between the pre-test and post-test results. This result indicates that the STEAM Learning treatment enhances students' understanding of electricity.

There was also an increase in each dimension of creativity. Table 4.7 shows Project 1 getting an average of 73.71%, which is categorized as enough. Then, in Table 4.10, project 2 gets an average of 83.13%, which is categorized as good. This shows an increase of 9.42%. It can be concluded that Paper Circuit Project-based STEAM Learning can Enhance Student Understanding and Creativity in Electricity.

Same as Hypothesis Ha. There is a significant difference in students' understanding and creativity before and after the implementation of electricity material and made paper circuit projects in STEAM learning. Overall, the study's outcomes demonstrate the effectiveness of STEAM Learning in improving students' comprehension and support its integration into the educational curriculum.

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