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The Effectiveness of STEAM-based Integrated Energy Conversion in Enhancing Critical Thinking Skills and Learning Outcomes

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Abstract

Critical thinking skill is one of the competences needed by the students. Implementing STEAM-based (Science, Technology, Engineering, Arts and Mathematics) learning in the classroom can trigger their critical thinking to develop as well as their learning outcome. This study aimed to describe the effectiveness of STEAM-based learning system in enhancing 4th grade students' critical thinking and leaerning outcome in Pati Regency. This quantitative-experimental study was conducted using quasi-experimental with pretest-posttest non-equivalent control group design. Two different schools in Kayen, Pati, were chosen as the subject of the research, and the samples were chosen randomly. There are in total 63 participants, of which 29 of them were chosen from SDN Rogomulyo and 32 students from SDN Pesagi 02. Data collection process was done by using documentation and multiple choices pretest-posttest. N-gain test and independent sample t-test were used for data analyzation. The results of this study showed that STEAM-based energy conversion was proven as effective in enhancing 4th grade students' critical thinking and their learning outcomes in Pati Regency. This can be seen from the results of the minimum criteria of effectiveness of the learning process after the subject received a treatment which is the implementation of STEAM-based learning.

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INTRODUCTION

Learning system in the 21th century has evolved from teacher-centered learning to student-centered learning. Mu'mainah and Suryaningsih (2020; Mertayasa et al., 2022) argued that learning process in the 21st century should be relevant with the needs and real life challenges. With that being said, critical thinking becomes one of the most important thinking skills that should be possessed to make sure productive contributions in this century. Critical thinking skill should be the center of the attention to fulfill the complex needs of the 21st century where they need to use critical thinking to solve real life problems (Siburian et al., 2019; Miterianifa, 2021).

Based on the observation process where the students were given problems, observation moduls arranged by the teacher, and also summative mid-test results at schools in Pati Regency, some problems were found related to the students critical thinking skill and learning outcome, especially in IPAS learning. These problems were raised because of some factors, for example the differences in students' competencies or the lack of effective lerning process. In reality, during the learning process, teachers only deliver the materials to the students and left them with the discussion among themselves as well as the tasks they were assigned to. This learning system affected the students' critical thinking skills which later affect their learning outcomes.

Based on the results of TIMSS (Trends in International Mathematics and Science Studies) in 2015, Indonesia was ranked 44 from 49 participants studied by the TIMSS on 4th grade students. The average score gained by the students in Indonesia was 397, below the international average scrore which is 500. Therefore, mathematical and scientific literacy of 4th grade students in Indonesia can be categorized in low level (low benchmark).

Derived from that, teachers need to give the students an effective learning that can triggers their critical thinking skills and produce a good learning outcome. Benjamin Samuel Bloom conducted a study and development on thinking skills during learning process which later known as Bloom Taxonomy. Krathwol (2002) argued, "Education taxonomy is a framework to classify our objectives or the students interests in order to know the results of the instruction." In the revised version of Bloom Taxonomy, high order thinking skills include analyzing (C4), evaluating (C5), and also creating (C6).

Teachers need to arrange a learning process that triggers their critical thinking skills as well as ehancing their learning outcome. One of the ways in enhancing critical thinking skills and learning outcomes is by using STEAM-based learning. STEAM-based learning model stimulate the students to face the challenges of the 21st century (Kartikasari, 2022).

In enhancing students' science learning outcome and science process skills, they need to be supported with content learning in the classroom which presented contextual learning to help the students comprehend with the phenomenas happening around them. One of the content learning that can be applied is STEAM-based learning that integrates one or more components of contextual learning. STEAM is the continuation of STEM (Dolgopolovas & Dagienė, 2021).

STEAM is a learning model that integrates science, technology, engineering, arts and mathematics as a tool in developing students observation, communication, and critical thinking during the learning process (Fitriyah & Ramadani, 2021; Wahyuningsih et al., 2020; Wirawan et al., 2022). STEAM gives the students chances to expand their knowledge, science, and humaniora as well as developing their 21st century skills (Siti Suryaningsih & Ainun Nisa, 2021). STEAM is a part of constructivism learning, which trained the students to build their own knowledge and understanding through projects. By using STEAM, students will possess and develop higher thinking skills that enhance their critical thinking, build logical thinking that can help them implement those skills when needed (Saban, 2023; Ananda, 2023).

STEAM required the students to comprehend learning as science, make use of the

technologies to find concepts with inquiry, then present them by paying attention to the ethics and aesthetics and display material forms using mathematical manifestation (Priantari et al., 2020). STEAM is a part of constructivism learning, which trained the students to actively build their own knowledge and understanding through projects.

The objective of this study is describing STEAM-based IPAS learning to enhance 4th grade students critical thinking skills and learning outcome in Pati Regency. As an effort to encourage the students to think critically thoroughly, and innovatively in formulating problem solving STEAM holds a huge part in training the students to understand the situation when facing the problems and think critically to solve them.

METHOD

This quantitative study is using experimental method with quasi experimental with pretest-posttest non-equivalent control group design. Experimental group received treatment by implementing STEAM-based learning, meanwhile control group did not receive any treatments. As displayed in Figure 1

$$E : O_1 \; X \; O_2$$
$$C : O_1 - O_2$$

Figure 1 Design of the Study

Desc:

E	: Eksperimental Group
C	: Control Group
O_1	: Pretest
O_2	: Posttest
X	: Treatment

This study was conducted in two different schools in Kayen subdistrict, Pati Regency with random samples taken from 4th grade students of SDN Rogomulyo 02 and SDN Pesagi 02. There were 29 samples from the first school as the experimental group and 32 samples from the latter as the control group. Data collection technique was done using documentation and pretest-posttest multiple choices problems for STEAM-based IPAS learning. Data analyzation process were going through some tests, namely N-Gain test and hypothesis test using independent sample t-test which aimed to compare before and after the treatment. Figure 2 below shows the stages of the study:

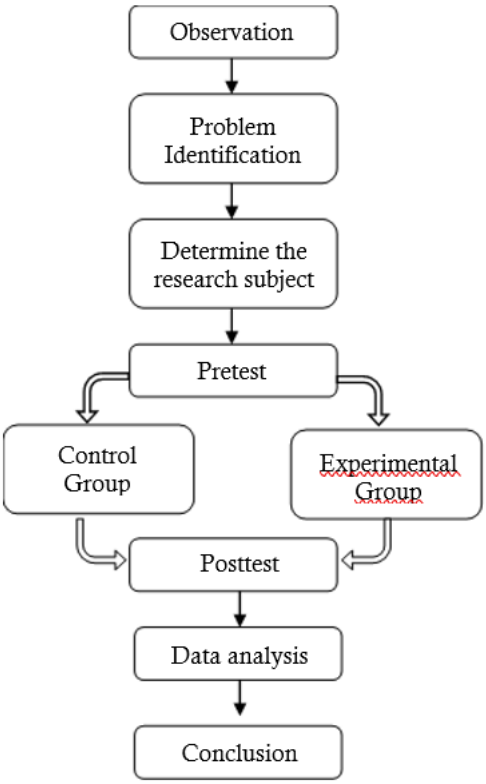

Figure 2 Stages of the Study

RESULTS AND DISCUSSION

Researcher conducted some observations at some schools which later identified the problems in those schools. The subject of the study was then chosen to obtain valid data. Furthermore, some learning tools such as learning module, learning objectives, and pretest-posttest probems were arranged.

This study was conducted four times in total for each group. The first meeting was where the students were given pre-test. The second and fourth meeting were a normal learning process where students receive materials like usual and the last meeting was conducted by giving them posttest. SDN Rogomulyo 02 as the experimental group was using STEAM-based learning during

those meetings. Meanwhile, SDN Pesagi 02 as the control group was using conventional learning method. Each meeting for ech school was 80 minutes long.

The subjects of the research are experimental group (SDN Rogomulyo 02) and control group (SDN Pesagi 02). In ensuring the fundamental of this research not influenced by external factors that can affect the results of the study, research samples were limited to 63 only, which divided into experimental group (SDN Rogomulyo) with 29 samples and control group (SDN Pesagi 02) with 34 samples. The sample of this research were those who attended classes in every meeting.

STEAM-based IPAS learning in this study started with finding the appropriate learning topic. The topic chosen for this study was energy conversion. The net step was to understand the content of student worksheet that was previously given to the students. The role of the researcher during this step was to observe and monitor the learning process. The last step was to train their creativism. The students were assigned to prepare the tools that would be used to create an appropriate design according to the worksheet. Researcher explained the steps in making the design to make sure the students understand the materials perfectly. Researcher then keep a cheek on the students during the process. Lastly, evaluation was done as the final step. With the help of the framework design, the researcher would easily conduct the study in order based on the design.

Moreover, the steps in STEAM-based learning include: (a) Students are free to explore the tools and materials being used in the classroom; (b) Teacher encourage the student to investigate and do a challenge (Extend); (c) Teacher encourage the students to engage in new learning experiences, associate their interests with the basic competence (Engage); and lastly, (e) Both students and the teacher should do a reflection (Evaluate).

STEAM-based IPAS learning is not entirely synonymous with project creations, instead, project creation is one of the main components of this learning method. STEAM-based learning is contextual aligning with current or past issues, thereby it can enhance students' problem-solving skill by identifying anf analyzing using scientific and mathematical aspects, as well as creating projects using technological technical, and art aspects (Putri & Taqiudin, 2021; Tan et al., 2021). Figure 3 below is the result of energy conversion experiment done by the students.

Figure 3 Result of Energy Conversion Experiment

Critical thinking skill was assessed using multiple choices test with a total of 20 problems. Ennis (Supriyati, 2018) argued that there are 5 indicators that can be used to assess critical thinking skill, namely: providing simple explanation (elementary clarification), building foundational skill (basic support), drawing conclusion (inference), providing further

explanation (advances clarification), and managing strategies and techniques (strategy and tactics) on 4th grade students' critical thinking skills towards STEAM-based IPAS learning.

Learning process required the students to adopt thinking and reasoning system in solving the problems they will be facing and it can be trigger to build students' critical thinking skill that will allow them to think and process everything in organized manner (Winoto & Prasetyo, 2020).

The first meeting in this study gained new information that there were some characteristics of thinking skills found in the control group as a result of the conventional learning. Students were able to give simple explanation (elementary clarification) with the percentage of 59.38%, building foundational skill with the same percentage of the previous indicator, 59.38%. The similar percentage was also found on the third indicator, drawing conlusion, where the students gained 58.85%. Two other indicators were having different percentages as the previos three, where the students were able to provide further explanation with the percentage of 62.07%, then managing strategies and techniques with the percentage of 60.92%. The average overall score obtained was 60.12, categorized as low.

On the last meeting of the research, the characteristics found on the control group changed. With convensional learning, students' percentage on each indicator of critical thinking skill proven to be increased. On providing simple explanation, they gained 69.53% in medium category. The next indicator is building foundational skill which gained 72.66% in medium category. Drawing conlusion gained 70.3%, also in medium category. Furthermore, providing further explanation and managing strategies and tactics gained a total of 73.56% and 77.01%, and the overall average was 72.72%, in medium category.

Meanwhile, the data gained from the experimental group showed that during the first meeting, all indicators were in low category. Students got 57.76% for providing simple explanation, 58.62% for building foundational skill, 63.22% for drawing conclusion, 56.32% for providing further explanation, and the last indicator, managing strategies and tactis, gained 52.87% with the overall average of 57.76%, in low category.

Moreover, the last meeting of the study for the experimental group seemed to gained an excellent result after implementing STEAM-based learning method for IPAS learning. On drawing conclusion, students were able to get 81.90%. A total percentage of 83.62% gained for the next indicator which is building foundational skill. On drawing conclusion, there was not much difference between the control group and the experimental group as the latter gained 79.89%. Meanwhile, the students were able to get 80.46% in both providing further explanation and managing strategies and tactis. The overall average of the last meeting for the experimental group was 81.26% and categorized as high.

These data were obtained after the meetings in both experimental and control class, during convensional or STEAM-based learning. The overall average for each group can be seen on the table below. Table 1 below shows the average score of pretest and posttest of the 4th grade studenys from control and experimental group.

Table 1 Average Score of Pretest and Posttest on Students' Critical Thinking

Class	Pretest	Posttest
Control	60.12	72.72
Experimental	57.76	81.26

Based on Table 1, it can be seen there's an improvement on the students' critical thinking skill in both control and experimental group. According to these results, it can be concluded that the critical thinking skill of the students in each group were improving, especially the group that implemented STEAM-based learning method. Figure 4 below is the diagram to compare the score pretest and posttest of control group.

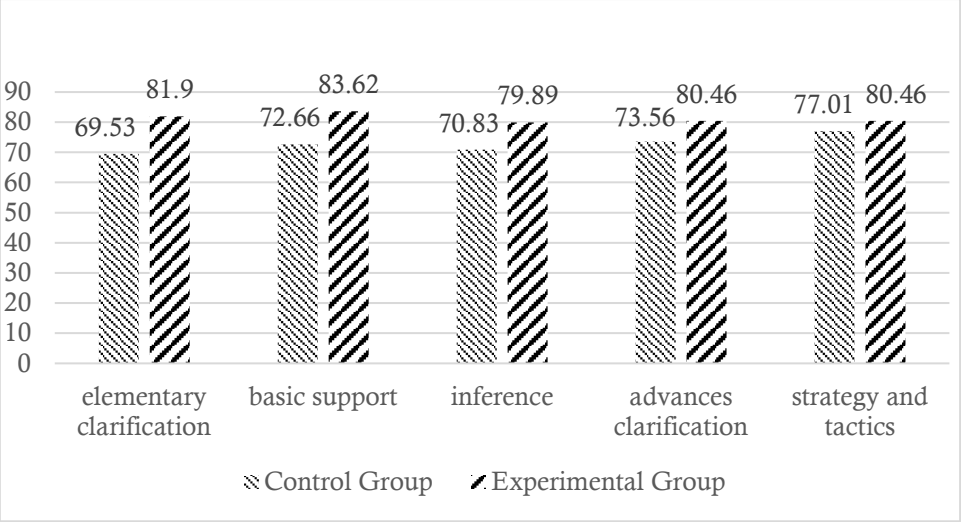

Figure 4 The Comparison of Critical Thinking Skill Control Group and Experimental Group

Based on the diagram, experimental group had the upper hand on the result of the students' critical thinking skill compared to the control group. The average score of the control group's critical thinking skills is 72.72 which has moderate category, with the highest indicator score on the basic support and the lowest score on the elementary classification. While the average value of the critical thinking skills of the experimental group has an average of 81.26 that have high category, the highest indicator value in basic support and the lowest value in the strategy and tactics indicator.

The reason behind this gap is because the control group did not apply STEAM-based learning method and only used conventional learning method. STEAM-based learning gives the chance to the students to fully develop their potential during the learning process (Rahmawati et al., 2021).

Achievement Test was used to determine the extent of students' learning outcome in the cognitive aspect after the implementation of STEAM-based IPAS learning and convensonal for Energy Conversion topic. The Achievement test was analyzed based on individual achievement against the indicators. The criteria in determining their minimum achievement criteria were based on the standards set by each school. In this case, both schools set the same standard for the Learning Objectives Achievement Criteria (KKTP), which is ≥ 70.

The difference found on the students' skills between the experimental group which applied STEAM-based learning and control group which only conducted convensional learning can be seen through figure 5 below.

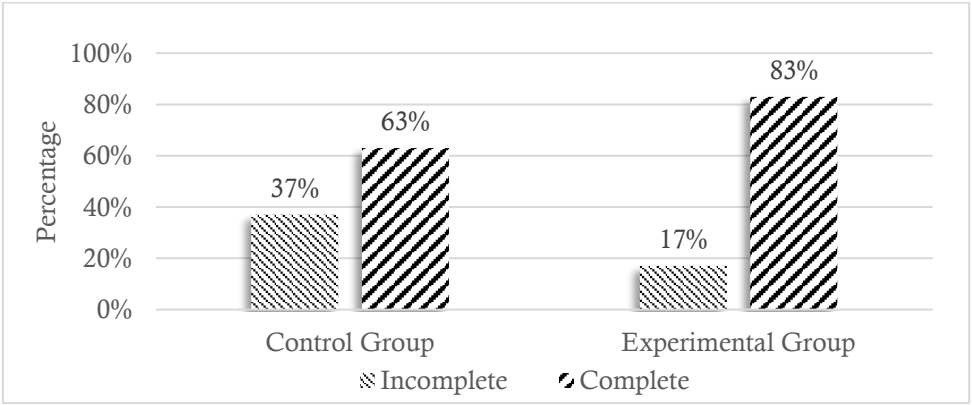

Figure 5 The Percentage of the Students' Learning Achievement

Based on figure 5, it can be seen that the percentage of the students learning achievements from experimental group was higher than control group. It showed that STEAM-based IPAS learning proven to be effective in enhancing students learning outcome in cognitive aspect. Table 2 below showed the average of each group's learning achievement on their pretest and posttest.

Table 2 Pretest and Posttest Average Score of 4th Grade Students Learning Outcome

Class	Pretest	Posttest
Control	58.13	69.53
Exsperimental	58.62	81.21

Table 2 above showed that there were some changes on the average score of pretest and posttest on both control and experimental group. It can be seen that experimental group had a higher score on the posttest than the control grup. To summarize, the students experienced an improvement on their learning outcome after receiving treatment of implementing STEAM-based learning. STEAM can enhance students cognitive learning outcome (Astuti, 2023; Handayani, 2023).

In order to find the effectiveness of a learning method, we need to at first conducting data analysis. The first test is normality test. Normality test is used to answer the normality of the data. The first data was the pretest score in solving critical thinking skill and learning outcome problems. Table 3 below is the result of the normality test in which Sig. > α (0,05) has normal distributions.

Table 3 Normality Test Results

	Class	Result of Data Analysis
STEAM-based learning	Experimental Pre	0.141
	Experimental Post	0.200
	Control Pre	0.101
	Control Post	0.116

On table 3, it can be showed that Sig value on experimental group pretest was 0,141 > 0,05 which means it has normal distribution and experimental posttest value was 0,200 > 0,05 and it also has normal distribution. On control group, it can be seen that the pretest has 0,101 > 0,05 which showed normal distribution, as well as posttest, Sig 0,116 > 0,05 means all data have normal distribution.

After obtaining informations refarding the total sample, pretest and posttest score of each group from SDN Rogomulyo 02 and SDN Pesagi 02, homogeneity test was done on both groups. Table 4 below shows the results of homogeneity test on both experimental and control group.

		Result of Data Analysis
IPAS Learning Outome	Based on Mean	0.364
	Based on Median	0.340
	Based on Median and with adjusted df	0.340
	Based on trimmed mean	0.380

Tabel 4 Homogeneity Test Resultsa

Based on table 4 above, IPAS learning outcomes of the 4th grade students of SDN Rogomulyo 02 and SDN Pesagi 02 on homogeneity test showed that those two groups considered homogeneous based on the mean which is 0,364, because the value is higher than 0,05 or 0,364 > 0,05. According to that rule, those data considered homogeneous. Now the data is ready to be proceed to the next test, hypothesis testing. On this research, hypothesis testing with parametric statistics was done to data with normal distributions. Researcher was using independent sample t-test to compare the results before and after receiving treatments. Table 5 below showed the results of independent t-test.

Tabel 5 Independent t-test Results

		Test Results
		Sig. (2-tailed)
Learning Outome	Equal variances assumed	0.001
	Equal variances not assumed	0.001

Based on table 5 above, it can be seen that the output of independent t-test result show sig value 0.001. 0.001 is less than 0.05 so H0 rejected and Ha accepted, which means there are some differences in the average of the learning output from experimental group and control group.

In ordet to investigate the effectiveness of STEAM-based IPAS learning, N-gain test was done to find out learning effectiveness after receiving treatment. By finding out the gap between pretest anf posttest score, we would know whether or not the implementation of a method proven to be effective. Table 6 below showed the N-gain (Hake, 1999) results in experimental and control group.

Tabel 6 N-gain Results

N Gain	Experimental Group (%)	Control Group (%)
	59.3212	28.9753

Formulation below was used with the intention of finding out the effectiveness STEAM-based IPAS learning model.

$$\text{Effectiveness} = \frac{\textbf{N-Gain Experimental Group}}{\textbf{N-Gain Control Group}}$$

$$\text{Effectiveness} = \frac{\mathbf{59.3212}}{\mathbf{28.9753}}$$

$$\text{Effectiveness} = 2.047302$$

Based on the the testing of the earning effectiveness, value is 2.047302 > 1, so it can be concluded that there' a difference between conventional learning STEAM-based learning which the latter is more effective. Based on t-test, it was known that independent output sample showed significant value of 0,001. 0,001 is less than 0,05 so H0 rejected and Ha accepted, which means there's a difference in the average score of their learning outcomes. This is in accordance with the study conducted by Fitriyah (2021), PjBL-based STEAM learning significantly affected the students' critical thinking skill with sig value 0,003 less than 0,05 and F-distribution value was 9,401. This can be happened because the integration of PjBL STEAM at the same time would be an innovation in the learning process that can build ideas and creative and critical solutions to ease the problem-solving process.

STEAM model can guide the students to possess some skills, such as problem-solving, critical thinking, and collaborative (Amelia & Marini, 2022). The implementation of STEAM-based PjBL significantly enhanced students' critical thinking skill (Indahwati et al., 2023; Syukri et al., 2022). STEAM-based learning had some positive impacts such as helping the students growing interest in science and mathematics, also problem-solving in real life. Moreover, Khoir (2021) argued that this model helps the students to become more creative, let them explore and motivate them to solve and formulating new ideas in solving any kinds of problems on their learning process.

STEAM-based learning is important to be implemented in elementary school to shape the students' mindset. STEAM is not solely related to formal education materials but more of training the students to be quick-witted and have a great sense of mindset, which also involves curiosity, preserverance, caring problem-solving, flexibility, daring to face challenges and taking any risks. STEAM is very much depend on the teacher in throwing questions to trigger their critical thinking skill. Teachers should consider about honing their skills to help stimulate the students. They can also challenge the students to think. The skill in stimulating the students' brain is called provocation. According to Siantajani (Reswari, 2021), provocation can be seen as one of the teacher's effort to always stimulate the students' natural tendency to look for meanings by asking questions and interpreting phenomena.

STEAM approach that combines science technology, engineering, arts, and mathematics in the learning process can foster curiosity and inspired them to have a high thinking skill such as problem-solving, independent, and learning development in real life battle, projects and research centers (Najamuddin et al., 2022).

STEAM can also give challenges and motivation to students because this method will gradually train the students to have critical thinking, able to analyze, and enhance their high thinking skills as well which assist the process of achieving desired learning outcomes. STEAM approach integrated with critical thinking skill will enhance students learning interest with meaningful lessons, and help the students in solving their problems be it during the learning process or in real life situations. Critical thinking skill holds a huge role in science learning (Lee, 2018).

Through STEAM-based IPAS learning, both the teacher and students will play an important and active role during the learning process to create a meaningful learning experience. Both teacher and students will collaborate to develop important skills needed for problem-solving. Based on those statements and minimum criteria, it can be concluded that STEAM-based IPAS learning is proven to be effective in enhancing critical thinking and

learning outcome of 4th grade students in Pati Regency especially SDN Rogomulyo 02.

Moreover, through this STEAM-based IPAS learning students will grow interest and actively participate in doing experiments about energy conversion during the learning process. Through experimental project carried out during the learning process, students will not only learn about the theory but as well experiencing it in real time. Hence, the whole learning process will give the students meaningful and constructive learning experiences. Other than that, STEAM-based IPAS learning also sharpen their creativity, collaborative skill, and other things that are the focus of STEAM-based learning.

There were some challenges faced by the researcher during the research process ni implementing STEAM-based learning. One of the challenges was the time allocation. It was not an easy task to adjust the time allocation that was planned beforehand with the actual time of learning in the classroom. This can be happened because STEAM-based learning focused on project-based learning so it was tricky for the teacher to have the ability to perfectly executed the plan with the time allocation because this learning method needs longer time to be prepared. This is in accordance with previous study which revealed that one of the challenges in implementing STEAM include time allocation and preparation problems (Herro et al., 2017; Shernoff et al., 2017). Challenges in STEAM-based learning are also include budgeting anf the lack of proper resources, especially in developing countries (Belbase et al, 2022).

Another challenge faced in the process of implementing STEAM-based learning is integrating every components of STEAM that will be used during the learning process. Tearchers are also need to stimulate the students by helping them doing or finishing an activity in the classroom. The limited boundaries that exist in STEM-based learning caused the teacher to only accompany and guide them through the learning process. Students play a full role over what they should do in the classroom to gain new knowledges. Though, teachers are the one who give them instructions during the learning process as well as at the end of the class to prevent misunderstanding among the students regarding the materials.

Tools and materials preparation for STEAM-based IPAS learning project became another challenge faced by the researcher. This problem arose mainly because of the difference of materials quality that affected the final results of the project. Tools preparation should be done perferctly too, because this is one of the crucial things to support the project carried out by the students.

CONCLUSION

STEAM-based energy conversion learning was proven to be effective in enhancing critical thinking skill and learning outcome of 4th grade students in Pati Regency. This can be concluded from the results of the minimum criteria of effectiveness of the learning process after the subject received a treatment which is the implementation of STEAM-based learning. T-test and N-gain testing also support the result of this study where the differences between the average score of students' critical thinking and learning outcome were found and experimental group has a higher score than the control group. In the implementation of further learning, the inference indicator needs to be improved because it has the lowest average even though it is in the moderate category and also other indicators especially basic support must be maintained as well as possible so that they remain in the high category. There was a strong relation between cognitive learning outcome and the critical thinking skill of the students through STEAM-based (Science, Technology, Engineering, Arts and Mathematics) integrated energy conversion, where the learning outcome highly influenced by their critical thinking skill. The more they develop their critical thinking skill, the higher their learning outcome become. Therefore, based on those statements above, STEAM-based (Science, Technology, Engineering, Arts and Mathematics) IPAS learning is effective in enhancing critical thinking skill and learning

outcome of 4th grade students in Pati Regency, especially SDN Rogomulyo 02.

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