The integration of STEAM-project-based learning to train students critical thinking skills in science learning through electrical bell project

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Abstract. This study uses qualitative methods describing the integration of STEAM-project-based learning with the aim of training the critical thinking skills of 18 male and 18 female students in science learning. The application of STEAM is done by integrating it with a project-based learning model on the topic of energy transformation through the electric bell project. Instruments are used to explore the development of critical thinking skills through interviews, observations, reflective journals, and critical thinking skills tests. The study found that students trained STEAM-PjBL to ask questions and have a good understanding of the energy change from electrical energy to sound energy. In addition, through problem solving and project creation, students are encouraged to connect ideas, make assumptions, and infer concepts. The challenges faced in this study are time management, project ideas related to teaching concepts, and student engagement. In addition, STEAM-PjBL integration provides an opportunity for teachers to develop their competencies in applying various methods to encourage students in the test results of the test students achieve mastering (40%) and competent (30%) at a critical level. Only temporary small (3.80%) students no concept of transformation correctly, even after knowing the distance.

1. Introduction
The rapid development in the era of contemporary technology has a significant impact on the education sector. Teachers are required to be able to develop their competencies in developing meaningful learning with the aim of improving students' thinking skills. Students need to have information and communication skills, scientific literacy, global awareness, cross-cultural thinking, and critical to be able to compete in the 21st century [1]. Critical thinking is one of the important skills that students need to do to solve various problems in daily life, as critical thinking skills cover the entire process of analyzing, evaluating, concluding, explaining, and communicating [2]. A process of metacognitive reflection that can be observed through students' ability to classify, reason, draw conclusions, make decisions, and solve problems [3]. Critical thinking skills can be trained through an interesting and meaningful learning process according to the subjects [4].

Critical thinking skills can be presented in STEAM's integrated meaningful learning of contextual learning that integrates five disciplines (Science, Technology, Engineering, Art, and Mathematics) in the learning process. This integration encourages students to think complexly and critically to solve problems in everyday life through project creation. STEAM implementation in learning can develop students' critical and creative thinking, problem solving skills, collaboration and argumentation skills, leadership and responsibility, information skills and literacy [5,6]. In addition, the application of project-based learning has the impact of developing critical thinking skills better than conventional learning [7].
Learning that can improve thinking skills is often experienced by students. In addition, proper learning in Indonesia is being applied with a variety of disciplines so that students' critical abilities can develop [8]. Students have the opportunity to use feedback in learning [9]. Creative teachers can develop preparing and developing learning in primary schools [10]. STEAM learning is a learning that can evoke the critical thinking skills of elementary school students [11]. STEAM, an Art-Based Learning Approach where learning activities appeal to students, making STEAM a fun learning.

Based on the above background, the researchers aimed to study the STEAM of learning science at the elementary school level for critical student skills. In this study, the topic of transformation. Whatever energy is power in everyday life and is an effect that students can exert. By 2019, it is important for elementary school students to learn the sources of energy and change. STEAM-PjBL is able to critical ability of students in understanding the concept of energy and its benefits in daily life [12].

2. Method
This paper illustrates the influence of STEAM-PjBL in the electric bell project to train students to think critically in learning about energy transformation. The participants consisted of 18 male students and 18 female students of a public elementary school in West Java. Learning activities are conducted more than 10 meetings in five weeks. The study used qualitative research methodology with several data collections through interviews, observations, reflective journals, and critical thinking skills tests. The data collected was analyzed using a critical thinking skills rubric which consists of five criteria [13], namely identifying the questions issued, conceptual understanding, connection of ideas, assumptions, and conclusions. STEAM-PjBL integration is implemented through five stages of learning as shown in Figure 1.

![Figure 1. Learning stages of STEAM-PjBL [12].](image)

3. Result and Discussion
The results show that the integration of STEAM-PjBL has developed students’ critical thinking skills. The implementation of STEAM-PjBL in science learning on the topic of energy transformation has been shown in Table 1.

| Science | Technology | Engineering | Art | Mathematics |
|---------|------------|-------------|-----|-------------|
| Energy transformation concept: Electrical energy becomes sound energy | Making a simple electrical bell | The process of converting electrical energy into a magnetic field to attract the electric bell beater | Decorate the device according to the creativity of the students | Geometry concept |
Table 1 shows that STEAM-PjBL provided the opportunities for students to develop the competences of hard skills and soft skills during learning process. Students' critical thinking skills were analyzed by researchers using five criteria of identify the question at issue, conceptual understanding, ideas connection, assumptions, and inferences [12]. Critical thinking tests are developed to assess the conceptual understanding of energy in contexts related to real-life situation to stimulate higher-order thinking skills. The critical thinking skills achievement level is shown in the Figure 2.

![Figure 2. The analysis of critical thinking level](image)

Figure 2 shows that STEAM-PjBL encourages students to practice their critical thinking skills, test results show that the majority of students achieve mastering (40%) and competent (30%) critical thinking. Only a small percentage (3.80%) students cannot define the concept of energy transformation correctly, even after an in-depth explanation is given. Most of the students showed conceptual understanding of energy, they understood the process of making a simple electric bell and explained how the bell produces sound due to the confluence of magnetic and copper fields.

### 3.1. Identify the question at issue

The learning material of changing electrical energy into sound energy is closely related to the currently developing technology and techniques. Therefore, undertaking a STEAM project based on sources of energy change encouraged the students' curiosity in relevant scientific phenomena. This phenomenon was demonstrated through the following dialogue.

**Quotation 1**

**Student 32**: Ma'am, can I do the project according to the procedure?

**Teacher**: Of course, you can work on the project, let's learn about the copper coil and magnetics then.

**Student 22**: Ma'am the ringing bell is not good, how about change it into the sound of music?

**Teacher**: Well, let's try any ideas to replace it, can you look for some information on the internet?

**Student 15**: Yes, ma'am

**Teacher**: Let's study the magnetic coil which becomes an electric field to trigger electric bell rang

**Student 10**: Ma'am, there is an electric bell at my house, I look something inside it, how does it work?

**Teacher**: The way it works is the same when we pressed coils and magnet, it can trigger the sound of the bell

The quotation above shows that STEAM-PjBL stimulated students critical thinking skills to explore energy transformation [13]. Student 10 has the ability to identify problems from real-life situation. In
this case, teacher has a role to facilitate students to make a conceptual analysis to make reasonable arguments.

3.2. Conceptual understanding

In developing a perception in learning, students must have a good conceptual understanding, so the ability to make arguments is based on student knowledge [14]. In this study, students are able to develop their conceptual understanding through STEAM project making activities which is indicated by students' ability to apply their initial understanding to solve the problems encountered.

“I understand how the bell can ring, because there is the presence of a magnetic field that functions as a pulling punch, so that when we give a punch or energy, it will produce sound”

(Reflective journal of Student 31, 5 February 2020)

The result of reflective journal above show that students have a conceptual understanding of the reactions that occur to produce sounds on the bell. This shows that project-based transdisciplinary learning encourages students to have a deeper understanding and enables them to solve a complex real-life problem [15].

3.3. Ideas connection

In this study, students are trained to be able to connect various ideas through project-making activities in groups. The study results show that students have been able to determine and use appropriate tools and materials in making projects, this is evidenced by the results of the following interview excerpt.

"When I formed the coil, I knew which tool was suitable for bending it, the shape of the tool was like a rotating drill, then I cut 5 inches in size, a hard plastic sheet like the back of a used cellphone, I tidied the edges so that it wasn't sharped then I colored it to make it looks interesting"

(Interview of Student 9, 5 February 2020)

The results of the study above show that students have simply been able to connect their knowledge of tools in everyday life that are suitable for use in making projects, and students can determine the type of material, size, and the importance of decorating as an expression of student creativity so that the project is interesting [16]. This proves that the integration of STEAM-PjBL as contextual based learning increases student involvement and provides meaningful learning through learning experiences they get from their own environment [17,18].

3.4. Assumptions

The development of assuming abilities in this study is characterized by the ability of students to propose an estimate that can be tested. The results of classroom observations show that students 7 in group 1 have been able to make the following assumptions.

"I found some important components in the electric bell that were electromagnets and circuit breakers. When the switched bell was pressed, an electric current flow towards the iron coil so that the paddle hit the bell then the bell rang"

(Classroom Observation, Student 7, 10 February 2020)

Student 7 has demonstrated a good level of understanding, so as to express assumptions that have been tested for truth and can be explained well by students. This proves that through project-based learning, students can understand how energy can change from electrical energy to sound energy. STEAM education encourages students to apply logical and scientific thinking that stimulates and enriches the learning experience. This is in line with [19,20] stating that STEM fosters student learning outcomes and reminds students of curiosity.

In addition, higher-order thinking skills in aspects of assumptions are also demonstrated through students' ability to ask questions, answer questions by linking information that has been received and
developed by [21] into answers, and the courage to express their views. This is evidenced by the class dialog below.

**Quotation 2**

Teacher : Do we need an electric bell and where do we need to place the electric bell?

Student 23 : Electric bells need to be provided in the community environment as a sign if there is theft or fire.

Teacher : Good, if so how can we distinguish which indicates theft and fire?

Student 12 : We can replace different tones, such as cell phone ringtones and connect it to speakers

The results show that teachers can help students to build their own meaning and knowledge through metacognitive processes to develop higher thinking skills [22].

3.5. Conclusion

Conclusion is one critical thinking skill that measures the ability to make clear, valid conclusions, logic, and support by adequate eviction. At the end of the electric bell project, students are asked to reflect their learning [23]. The following reflective journal shows that 18 students tried to reveal the cause of the imperfect results of the group 3 project.

"I made a mistake in the material preparation stage, I put the coil not in accordance with the instructions, and the number of copper coils is less than instructed, so the movement of the magnetic field is not perfect then the sound of the bell does not ring loudly"

*(Student Reflective Journal 18, February 10, 2020)*

The above student statement indicates that the student has been able to draw conclusions from the failure of the creation of the project and it is supported by logical reasons. In addition, the development of critical thinking skills is also characterized by the following reflective student journals.

"Through project creation activities, I can conclude that the magnetic field is being affected by strong electric current flowing, the number of turns, relay materials and speakers that make the electric bell ring stronger"

*(Student Reflective Journal 22, 10 February 2020)*

The above results show that the integration of STEAM-PjBL in science learning can develop students' critical thinking skills demonstrated by the ability of students to examine evidence to make consistent, logical, and credible conclusions [23].

4. Conclusion

The analysis of five critical thinking criteria indicated that STEAM-PjBL can applied in science learning to train elementary school students critical thinking skills. The findings of the study showed that electrical bell project encouraged students to develop metacognitive understanding on energy transformation from electrical energy into sound energy. In addition, students also able to make an investigation to make clear and logical statement to explain the failure causes of their project. The implementation of STEAM-PjBL has been trained student to make connection between concept they learned in school and real-life situation, so students get the meaningful learning. The integration of arts is an innovation in science classroom to enhance student motivation and become a fun learning for students. As for the challenges faced by researchers during conducting research are time management, project ideas that are appropriate to the learning topic and in accordance with the level of student education, and student involvement in learning. The integration of STEAM-PjBL also encourages teachers to develop their competence in applying various learning approaches that are interesting for students. In this study, students also given the opportunity to develop their communication, collaboration, and problem solving through STEAM project making.
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