The Analysis of Low Carbon STEM Project Implementation on Science Learning

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Abstract. The research aims to examine the Low Carbon STEM Project implementation in science learning from the perspectives of teachers and students. This study employs a qualitative approach with a systematic approach. Techniques for gathering data include observation, documentation, open questionnaires, and interviews. Teachers and students from grade 9 used the Low Carbon STEM Project as research subjects. Data analysis is qualitative, in which the data is analyzed based on the field results. The results revealed that the teacher had implemented the Low Carbon STEM Project centered on students using the Engineering Design Process (EDP) technique, with the stages of define, learn, plan, try, test, and decide. However, there are still some challenges, including a lack of teacher support and awareness of Low Carbon STEM project-based learning, technical obstacles, time constraints, and access to technology-based facilities.

Keywords: Low Carbon, STEM Project, Science Learning

1 Introduction

The development of the 21st century is known as the knowledge century, the age of the knowledge-based economy, the century of information technology, globalization, and the industrial revolution 4.0 [1]. The characterization of industrial revolution 4.0 is rapid and massive technological advancements that have the potential to alter all aspects of human life; as a result, humans must possess high competence in order to survive [2]. The ability of human resources to survive in the 21st century is inextricable from the education sector's role. Changes and developments in the field of education necessitate qualified and competent human resources for the field to adapt to changing times [3]. The required skills include life and career skills, media and information, critical learning and innovation, and technological skills [4]. In the 21st century, technology skills are essential skills.

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Rapid and massive technological developments should be balanced with new technological innovations; however, the reality on the ground is that the majority of teachers in schools are still reiterating facts and concepts and have not maximized new technological engineering. A deficiency also hinders schools' lack of technological engineering development in facilities and infrastructure for science education. Har's (2019) research demonstrates that learning in the classroom with science literacy and learning in the laboratory through experiments contribute significantly to students' technological skills; therefore, technology-based classroom learning is essential [5].

Increasing technological renewal and competitiveness can be made more creative, one method being the STEM learning approach [6]. By placing science and mathematics in the context of technology and engineering, STEM learning is an effective way to engage students in higher-order thinking and improve problem-solving skills [7]. STEM education requires students to be innovators, problem-solvers, inventors, think logically, and be technologically literate [8]. The STEM learning utilized in the study is environmentally friendly (Low Carbon) STEM learning conducted as a project. Low Carbon STEM is a more practical approach for developing creative thinking skills. By incorporating the low carbon concept into the learning process, students can better understand the low carbon principles, concepts, and attitudes necessary to reduce carbon emissions [9]. Based on Capraro et.all (2013) show that Low Carbon STEM requires students to solve a problem using a project. Low Carbon STEM and discovery learning help students improve their creative thinking skills, but they work in different ways. In classes that use Low Carbon STEM, students learn about real-world problems and then design and do a project to solve them. The project in this study also helps students learn about sustainable development because they make STEM projects that are environmentally friendly or use less energy [10]. This supported by Akhmad et al. (2020) Low Carbon STEM is more effective for improving creative thinking skills [11]. PJBL-Low Carbon STEM can improve 21st-century skills: innovation skills and flexibility skills [12]

The Low Carbon STEM Project is an eco-friendly learning project that employs the EDP (Engineering Design Process) phase in its implementation. Define, learn, plan, try, test, and decide are the EDP phases [13]. "Define" is defining the phenomenon that occurs, "Learn" is the use of scientific concepts in solving problems, and "Plan" is creating solutions by linking the use of scientific concepts. "Try" is implementing solutions based on information tailored to the problem, and "Test" is reevaluating the design of solutions based on information. "Decide" that drawing conclusions about the design's benefits and drawbacks is appropriate based on the previously obtained information. The research adopted a six-stage EDP from a STEM Center of the University of Minnesota and Purdue University design [14].

In order to increase the production of new engineering technologies and enhance the environmental science education standard, the Low Carbon STEM Project is applied to the Basic Science Competencies of junior high school that are in line with environmentally friendly topics. One of the required products to be given in learning to support education for sustainable development is environmentally friendly STEM projects. Teachers should carry out eco-friendly projects as part of a learning community for sustainable learning [15]. Based on the justifications mentioned earlier, this study will implement the Low Carbon STEM Project learning in science instruction before examining the implementation from the perspectives of teachers and students.

2 Research Questions

This study investigates the differences between teachers' and students' opinions on the Low Carbon STEM Project learning in science education. This research is anticipated to result in innovations in STEM-based learning from an objective perspective, namely changes based on the characteristics of students learning science that can handle all obstacles and issues in the field.

3 Background Literature

3.1 Low Carbon

Developed countries have widely used the Low Carbon concept to reduce greenhouse gas (GHG) emissions, utilize low-carbon energy, and ensure sustainable economic growth. Sustainable development should apply the Low Carbon concept in practice because the technology significantly reduces climate warming, energy crisis, and sustainable development [16] [17].

3.2 STEM

STEM is learning that logically, realistically, and comprehensively integrates the four disciplines of Science, Technology, Engineering, and Mathematics [18]. At least two of the four STEM components can be employed in combination to achieve the required learning objectives. STEM learning could develop conceptual knowledge of how STEM learning that incorporates many scientific domains is interactive and adaptable [19].

3.3 Low Carbon STEM Project

The Low Carbon STEM Project is a learning project packed in the form of a STEM approach with the EDP (Engineering Design Process) technique consisting of the steps Define, Learn, Plan, Try, Test, and Decide that apply the notion of low carbon or ecologically friendly. Science, technology, engineering, and mathematics (STEM) projects that do not harm the environment are one of the required learning products that support education for sustainable development. Teachers must undertake environmentally friendly projects as part of a sustainable learning community [15], [20].

3.4 Science Education

Science is a collection of concepts, principles, laws, and theories formed through inquiry followed by a continuous (empirical) observation process; it is a human effort that includes mental operations, skills, and strategies to manipulate and calculate, which can be verified again based on an attitude of curiosity, determination, and perseverance to uncover the secrets of the universe [21]. Science learning is guided by the nature of science, including its procedures, products, and attitudes. Science education has the potential to enhance environmental-based education and build an environmental consciousness [22].

4 Methods

This study employs a systematic qualitative methodology. Observation, documentation, open questionnares, and interviews are all forms of data collection procedures. The study subjects were ninth-grade teachers and students who utilized the Low Carbon STEM Project pedagogy. The notion of electrical circuits, electrical energy and power, and the sources of electrical energy in daily life, including alternative sources of electrical energy and various measures to save electrical energy, are implemented. Qualitative data analysis examines data based on open questionnaires filled out by teachers and students, then bolstered through field observations, documentation, and interviews with teachers and students.

5 Results

The open questionnaire offered to students and instructors addressing Low Carbon STEM consists of five questions: 1) What does Low Carbon STEM Project Learning mean, 2) How is the Low Carbon STEM Project implementation learning-centered, 3) Implementing the Low Carbon STEM Project in science learning is simple, 4) Does the Low Carbon STEM Project learning make it easier to comprehend the material, 5) What challenges are associated with implementing the Low Carbon STEM Project learning. The student's open-ended questionnaire responses have been collated in Table 1:

Table 1. Student questionnaire results

No	Item	Students' Response
1	What is the Low Carbon STEM Project learning?	➢ Learning tools packaged in the form of projects ➢ Environmentally friendly project ➢ Chemical energy from natural materials can be converted into electrical energy ➢ Learning in the form of fruit and vegetable practice ➢ Do not know

No	Item	Students' Response
2	How to execute the Low Carbon STEM Project learning?	➢ Fun, learn new things ➢ Practiced ➢ Easy to understand and interesting ➢ Good to apply ➢ More complicated and difficult to understand because of a lot of thinking
3	Is it simple to implement the Low Carbon STEM Project learning?	➢ Easy ➢ Pretty Easy ➢ Easy because it is done with practice and fun
4	Does the Low Carbon STEM Project make the comprehension of the material easier?	➢ Because it is done directly not only theory ➢ Because it is easier because you practice directly and immediately know the facts ➢ Because it is interesting ➢ Because it is done earnestly and seriously ➢ Because it is easy to understand
5	What are the obstacles to implementing the Low Carbon STEM Project learning?	➢ The teacher only gives a little material / concept, so you have to think a lot to be able to expand the material ➢ Because not all students have the same creativity ➢ No difficulties

The teacher's open questionnaire consists of 10 problem items: 1) whether science learning has implemented an integrated approach to science learning; and 2) whether science learning has used a technology-integrated learning method. 3) An integrated engineering learning strategy has been adopted for science learning. 4) Whether a mathematics-integrated approach to science education has been implemented. 5) Whether science education has incorporated a STEM (Science, Technology, Engineering, and Mathematics) integrated learning strategy; 6) Whether science education has incorporated eco-friendly technologies (low carbon); 7) If you have not already, please describe the barriers to STEM and Low Carbon learning; 8) What does Low Carbon STEM Project learning to entail; 9) Is it crucial that schools implement the Low Carbon STEM Project instructional approach; 10) The use of the Low Carbon STEM Project curriculum at the junior high school level, particularly in science education.

Based on the teacher's responses to an open questionnaire, the following data was gathered: 1) Science-integrated learning has only been implemented in 50% of schools; 2) No, because not all facilities are in place; 3) No, because not all facilities are in place; 4) Not yet implemented; 5) not implemented because learning is still oriented on the teacher; 6) not implemented, 7) Because of insufficient facilities, time, and instructional hours; 8) Students engage in STEM-based project-based learning by applying environmentally responsible concepts; 9) It is crucial because it encourages students to be autonomous learners, fosters creativity, expands knowledge in the form of projects, and emphasizes the significance of eco-friendly principles; 10) It is excellent because it instills eco-friendly learning.

6 Discussions

6.1 Analysis of Implementation from the Student's Perspective

Based on the results of the open questionnaire reported in Table 1 and bolstered by student interviews, the following conclusions were reached: 1) The majority of students are aware that Low Carbon STEM Project learning is packaged in the form of ecologically responsible projects using fruits and vegetables that store chemical energy in nature. It can be transformed into electrical energy and is utilized in practice. 2) Implementation in the classroom based on students' perceptions that learning the Low Carbon STEM Project is learning that is carried out in practice to be easy to understand and comprehend, very good to implement in lessons because it is enjoyable and encourages students to think more critically when solving problems. 3) Implementing Low Carbon STEM Project learning is simple since learning via projects and practices is more enjoyable. 4) The direct nature of Low Carbon STEM Project instruction facilitates student comprehension of the subject content by memorizing theory and practice. The facts and concepts are quickly learned by students, making learning fascinating and straightforward. They also believe that studying can be more severe and rigorous; 5) Difficulties in applying Low Carbon STEM Project learning because the teacher only provides a small amount of material or concept, necessitating a great deal of thought to be able to expand the material in order to achieve the desired design, as students do not share the same level of creativity, resulting in different final project outcomes for each group.

The outcomes of student observations made during direct instruction in Low Carbon STEM Project learning have increased skills in observing and organizing electrical circuit tools and materials, problem-solving and designing electrical circuits, observing the results of a series of trials and tabulating them in reports, and concluding experimental results based on the presented material. STEM learning can create harmonious, dynamic, engaging, and demanding classrooms in addition to fostering student independence, technology literacy, and inventiveness [23]. STEM learning also encourages students' scientific literacy and technology, seen through reading, writing, observing, and practicing science, so that it may be used to live in society and address problems connected to STEM science encountered in everyday life [18]. Integrating STEM learning with project learning can boost student engagement, make learning more colorful, assist students in solving real-world challenges, and support future jobs [10]. Project-based learning can excite and challenge students since it cultivates critical thinking, analysis, and higher-order thinking [10]. Based on the theoretical explanation and research findings, it is envisaged that environmentally friendly project-based STEM learning will increase students' appreciation for the environment and encourage them to continue preserving it to support sustainable development.

6.2 Implementation Analysis from the perspective of the instructor

According to the results of open questionnaires, teacher interviews, observations, and documentation from the teachers, before implementing the Low Carbon STEM Project learning, teachers had never used the STEM approach simultaneously or the single integration of science with technology, engineering, or mathematics. Teachers have taught science in an integrated fashion, incorporating physics, chemistry, biology, and earth and space sciences, but have not incorporated STEM components. 50 % of learning has been conducted through practice or experimentation without using STEM, whereas 50 % of learning is still conducted through traditional lecture and question and answer methods, the majority of which are still teacher-centered. In addition to not utilizing STEM learning in schools, they have also not maximized learning that is low carbon or environmentally friendly. The school facilities have not been completely satisfied. The facilities and infrastructure do not yet allow STEM Low Carbon learning, and the time and number of class hours are insufficient to teach all basic competency with STEM Low Carbon, but we will attempt to do so because children are more engaged and eager to solve challenges. The final cognitive basic competency test scores of the class that adopted the Low Carbon STEM Project learning were also higher than those of classes that did not apply the Low Carbon STEM Project learning. The teacher believes it is essential to teach Low Carbon STEM Project at the junior high school level because it fosters student independence in learning, increases their creativity, expands their knowledge of group project creation, and enables them to comprehend the concept of environmentally friendly education.

According to Firdaus and Rahayu (2019), STEM-based learning can enhance students' cognitive capacities. Teachers must still use science, technology, engineering, and mathematics in the actual world [24]. Thomas and William's (2010) review demonstrates that the application of STEM in schools must be supported in multiple ways, including 1) involving and supporting the interests of students whose skills and needs are not being met; 2) providing the opportunities and resources necessary to improve STEM learning and teaching; and 3) developing students' skills according to the field [25]. STEM is essential to explore the negotiation between science and engineering components, especially in the classroom setting [13].

7 Conclusions

The outcomes demonstrated that the instructor had implemented the Low Carbon STEM Project curriculum utilizing the Engineering Design Process (EDP) technique, which was student-centered and comprised of the phases define, learn, plan, try, and decide. However, there are still some obstacles, such as the need for technical training for teachers concerning the implementation of the Low Carbon STEM project and the provision of supporting facilities, particularly technology-based facilities, to facilitate the implementation of the Low Carbon STEM project in schools. With the practice of learning based on the Low Carbon STEM project, student motivation can increase, allowing them to comprehend and apply scientific concepts more quickly and directly. In addition, the Low Carbon STEM project learning can enhance youths' creativity and problem-solving skills. However, implementing Low Carbon STEM learning faces several obstacles, including a lack of teacher support and awareness of Low Carbon STEM project-based learning, technical obstacles, time constraints, and access to technology-based facilities.

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