CHAPTER I

INTRODUCTION

1.1 Research Background

Energy is one of the critical factors in achieving sustainable development (Setyono & Kiono, 2021). Energy is an essential foundation for economic activities, such as industrial operations and transportation, and supports social aspects, such as providing electricity for education and health and environmental aspects through efficient resource management. Humans rely heavily on energy to carry out various activities, ranging from household needs to industrial activities. Examples of energy in daily life are electrical, thermal, kinetic, and others.

In the current era of globalization, of course, energy needs are one of the most important things. Increasing energy demand that is not balanced by energy production causes vulnerability to the condition of national energy security (Al Bahij et al., 2020). National energy security is the capacity of a country to deal with changes in the global energy situation while ensuring energy supplies remain available domestically. In fact, dependence on fossil energy such as coal, oil and natural gas still dominates, given its role as the main source to meet national energy needs. However, dwindling fossil energy reserves pose a serious threat to the sustainability of the energy supply in the future. According to Afin & Kiono (2021) Citing information provided by the Indonesian Ministry of Energy and Mineral Resources, Indonesia's coal reserves are expected to run out in approximately 83 years if current production levels continue. In addition, other supporting data are found in the data on petroleum reserves in Indonesia. According to Rahmayanti et al. (2021) who obtained data from the Ministry of Energy and Mineral Resources, Indonesia's oil reserves are only available for 9.5 years and natural gas for 19.9 years assuming no new discoveries of oil and gas reserves. This shows the importance of energy transition to more sustainable sources.

A more sustainable transition to renewable sources is to shift towards the use of renewable energy. Renewable energy comes from unlimited sources, produces very low greenhouse gas emissions into the atmosphere, and is more economical than conventional energy (Marks-Bielska et al., 2020). Indonesia has various abundant renewable energy sources, such as wind energy, solar energy, water energy, geothermal energy, bioenergy, nuclear energy, and ocean current energy (Murniati, 2022). This abundant renewable energy is due to the strategic geographical location of Indonesia, which is in the equatorial region. One of the growing renewable energies is wind energy. In Indonesia, the potential for wind energy is very large, especially in coastal areas. This is because Indonesia is an archipelago with a very long coastline, so the potential for wind energy in the area is quite high. The utilization of wind energy is very useful as an efficient and environmentally friendly alternative energy to reduce dependence on fossil energy. One way of utilizing it is through wind turbines to generate electricity. However, based on the *Balai Besar Survei dan Pengujian Ketenagalistrikan Energi Baru (2021)*, the target capacity of PLT-*Angin* (Wind Power Plant) in 2025 is 255 MW. Meanwhile, until 2020, the new wind power plant installed was around 135 MW. Therefore, the development of wind energy in Indonesia remains a major challenge that must be faced nationally.

The government has a target for the use of renewable energy. According to the Ministry of Energy and Mineral Resources (2017), Government Regulation No. 79 of 2014 concerning the National Energy Policy (KEN) and Presidential Regulation No. 22 of 2017 concerning the National Energy General Plan (RUEN) have targets for the use of renewable energy in 2025 and 2050 of 23% and 31% of total national energy needs, respectively.

According to Minas et al. (2024) The transition to renewable energy has become a main focus in global talks on sustainable development, driven by the need to reduce climate change and ensure energy for future generations. To realize the transition to renewable energy requires self-awareness. The success of this transition greatly depends on public awareness of renewable energy technology, including knowledge, perceived benefits, and community support (Wall et al., 2021). This awareness involves understanding the importance of protecting the environment, reducing greenhouse gas emissions, and the positive impact of using renewable energy for the future.

A study found that the level of self-awareness in students is still low regarding renewable energy. According to Eshiemogie et al. (2022), most of the respondents, 87%, were final-year engineering students, while 13% were from earlier years. Nearly all of them (98.1%) reported knowing about renewable energy, but only 24% felt very confident in their knowledge. Approximately 35.2% rated their confidence at level 3 on a 1-5 scale. Additionally, 76% mentioned that renewable energy was not part of their studies, despite 98% having heard about it. Another finding is from Çakirlar Altuntaş & Turan (2018) who stated that although the school was found to be the students' primary source of information about renewable energy, the awareness level of the students who studied the subject in school was lower than that of the students who learned about it from scientific and popular magazines and those who learned about it from their families. The low level of student awareness is due to a lack of learning. This highlights the need for further learning on the topic of renewable energy, enabling students to appreciate the importance of this resource.

Education plays an important role in shaping students' mindsets. Through education, students can gain an understanding of the benefits of renewable energy, its impact on the environment, and their role in supporting the sustainability of life on Earth. One effective way to achieve this is by implementing student-centered learning that involves active participation and problem-solving through authentic experiences. The STEM (Science, Technology, Engineering, and Mathematics) learning model provides an interdisciplinary approach that connects scientific concepts, engineering practices, and technological applications to real-life contexts. According to Nugraha et al. (2024), interdisciplinary STEM education connects scientific concepts, engineering practices, and technology applications in real-world contexts. This model emphasizes active engagement, collaboration, and discovery-based exploration, which are essential for preparing students to face the challenges of the 21st century.

The implementation of STEM learning has been shown to improve students' critical thinking skills. Critical thinking encompasses the ability to analyze information, identify supporting evidence, recognize and evaluate assumptions, and draw conclusions based on sound reasoning (Seventika et al., 2018). These skills are also one of the benchmarks for the International Student Assessment Program (PISA) in measuring the quality of education. The PISA test assesses how well students understand and perform in reading, mathematics, and science. Each test focuses on one subject and provides a brief overview of the other two. However, according to the OECD (2019), Indonesian students scored an average of 396 points in science, far below the OECD average of 489 points. The data shows that students' critical thinking skills are below the global average. This indicates that students still tend to memorize information rather than apply their scientific knowledge to solve real-life problems (Aydin et al. 2024). According to Mabrurah et al. (2023), students' critical thinking abilities can be enhanced through STEM-based learning, as this paradigm provides opportunities for them to research, explore, and address meaningful and challenging problems.

Nevertheless, the use of the STEM model often lacks a clear structure to ensure that students consistently evaluate, revise, and improve the solutions they design. Sumanti et al. (2025) highlight that while STEM encourages collaboration, it requires a framework that supports continuous reflection and iterative improvement. To overcome this limitation, integrating the Engineering Design Process (EDP) offers a systematic approach to strengthen STEM learning. EDP introduces iterative steps such as identifying problems, generating solutions, building prototypes, testing, and evaluating results. This structure gives students a deeper and more reflective way of thinking while engaging in hands-on problem-solving. According to Fatiin et al. (2024), integrating STEM with the Engineering Design Process enables students to take an active role in teamwork by exchanging ideas and taking concrete actions in designing solutions. Vistara et al. (2022)also emphasize that STEM-EDP integration supports creative thinking by guiding students to create innovative designs and products that reflect their originality. Furthermore, Lin et al. (2021),found that embedding EDP into the STEM curriculum enhances students' design skills, problem-solving abilities, and reflective practices in producing solutions. Thus, the integration of STEM learning with the Engineering Design Process (EDP) provides a strong foundation to foster students' awareness and critical thinking. It equips them with not only conceptual knowledge but also the mindset and skills needed to engage in sustainable problem-solving for real-world challenges.

Several previous studies have discussed the application of STEM learning model and its integration with the Engineering Design Process (EDP) in improving the quality of learning. For instance, Abdurrahman et al. (2023) found that integrating engineering design process into STEM can foster students' system thinking skills on renewable energy unit. Research by Jihni et al. (2024) shows that STEM-Engineering Design Process (STEM-EDP) can improve students' learning motivation on solar system topic. Another study conducted by Sapphira et al. (2023) shows that the STEM-based Engineering Design Process (EDP) learning model can improve students' critical thinking skills. Additionally, Chairunnisya et al. (2023) found that integrating the Engineering Design Process (EDP) with PjBL-STEM can stimulate numeracy literacy skills in the topic of renewable energy.

This research gap indicates that there are still limited studies in Indonesia that specifically investigate the integration of the STEM learning model with the Engineering Design Process (EDP) to enhance students' renewable energy awareness and critical thinking skills, particularly within the context of renewable energy. Therefore, the novelty of this study lies in implementing a STEM-EDP learning approach through a wind turbine project. This approach is designed not only to foster students' critical thinking abilities but also to raise their awareness of the importance of renewable energy for sustainable development.

According to background stated, this study aims to implement the integration of STEM learning model and the Engineering Design Process to improve students' renewable energy awareness and critical thinking skills in the topic of renewable energy. Therefore, the title of this research is "Engineering Design Process-Based STEM on Wind Turbine Project to Strengthen Students' Renewable Energy Awareness and Critical Thinking Skills".

1.2 Research Problem

According to the background that has already been stated, the problem in this research is "How does STEM with Engineering Design Process (EDP) strengthen students' renewable energy awareness and critical thinking skills?"

Several research questions are derived from the research problem to be investigated. The research questions are listed below:

1. How does STEM with the Engineering Design Process (EDP) affect students' renewable energy awareness compared to STEM project-based learning without EDP?
2. How does STEM with the Engineering Design Process (EDP) affect students' critical thinking skills compared to STEM project-based learning without EDP?
3. How does the correlation among STEM with Engineering Design Process (EDP), students' renewable energy awareness and critical thinking skills?

1.3 Operational Definitions

To avoid differences in interpretation of the terms used in this study, it is necessary to explain the operational definitions of each variable studied. These operational definitions aim to provide clear boundaries for the concepts used, thereby facilitating the measurement and analysis of data. The main terms in this study include STEM learning model, Engineering Design Process (EDP), STEM with Engineering Design Process, students' renewable energy awareness, and students' critical thinking skills.

1. STEM learning model

   The STEM learning model in this research refers to an interdisciplinary instructional approach that integrates Science, Technology, Engineering, and

Mathematics to address real-life contexts. This model emphasizes inquiry, exploration, and problem-solving, where students actively engage in identifying problems, analyzing scientific principles, applying engineering practices, and utilizing technology to develop solutions. According to Widodo (2021), there are six stages of STEM learning model, which are: identify the problem, think, design, create, test, and redesign.

2. Engineering Design Process (EDP)

Engineering Design Process is a learning approach with an engineering context to assist students in problem-solving using the creative and systematic thinking process. In this research, EDP was employed as a structure and support for students on creating solutions, generating ideas, and making simple prototypes in the field of renewable energy. EDP helps students to investigate, decide and reflect the way in which they work both in an orderly and structured way. The engineering design process has seven stages, which are: identify the need or problem, research the need or problem, draw/sketch possible ideas/solutions for the problem, select the best possible solution(s), design and construct a prototype, test and evaluate the solution(s), and communicate the solution(s) (Siew et al., 2016).

3. STEM with Engineering Design Process

The STEM with EDP model in this study is defined as a learning model that integrates STEM project-based activities with the systematic stages of the Engineering Design Process (EDP) to solve engineering problems. In practice, this model was implemented through group project-based classroom activities where students designed and built a wind turbine as a representation of a renewable energy application.

The learning process guides students through several stages, including identifying problems, gathering relevant information, generating and selecting design solutions, creating a project schedule, monitoring progress, constructing and testing prototypes, presenting project results, and reflecting on their experiences. These activities are supported by structured learning tools such as lesson plans, student worksheets, and teacher observation guidelines.

Through this approach, students not only learn integrated STEM concepts but are also trained to think critically and creatively, collaborate effectively, and apply problem-solving skills to real-world contexts related to renewable energy.

4. Students' Renewable Energy Awareness

Student awareness reflects the extent to which the student understands, cares about, and is sensitive to an issue or topic. It allows students to see things from a different perspective and it helps students break away from prejudices and assumptions. In this research, the awareness of students in renewable energy topic will be measured using questionnaire in the form of a Likert scale. This Likert scale is designed to assess students' behavioral aspects. Later, students will complete this questionnaire during the pretest, and then will be retested through the post-test after applying the lesson on the topic of renewable energy.

The instrument for assessing students' awareness was adopted from Kacan (2015). The instrument only covers the aspects designed in the questionnaire and relies on students' honesty and understanding of the statements in the questionnaire given during the Pre-test and Post-test to see if there is an improvement in students.

5. Students' Critical Thinking Skills

Critical thinking skills is one of the 21st century skills that will help students to learn. It refers to the ability to process information in a structured way through analysis, evaluation, and logical reasoning, aimed at solving problems, making the right decisions, and concluding based on available evidence. In this research, critical thinking skills of students will be measured using a type of test item through Pre-test and Post-test in the form of open-ended essay questions that related to the topic of renewable energy.

The assessment rubric to assess this critical thinking skills are from Ennis & Weir (1985) that was adopted by Ijirana et al. which states that the critical thinking skills instrument includes several indicators in it, which are, determine the actions, developing basic skills, evaluating the statements, identifying the assumption, also the clarification and evaluation.

1.4 Research Objectives

The following are the aims of this research based on the problem that has been proposed:

a. To investigate the effect of STEM with the Engineering Design Process (EDP) on students' renewable energy awareness compared to STEM project-based learning without EDP.
b. To investigate the effect of STEM with the Engineering Design Process (EDP) on students' critical thinking skills compared to STEM project-based learning without EDP.
c. To investigate correlation between the implementation of STEM with Engineering Design Process (EDP) and students' renewable energy awareness and critical thinking skills.

1.5 Research Benefits

The result of this research is expected to provide the following benefits:

1. For students, this research is useful so that students can better understand and sharpen their critical thinking skills on the topic of renewable energy. In addition, this research is also useful so that students are more aware and care about the importance of these topics for the sustainability of life. Through the wind turbine project, students are encouraged to learn by doing, which makes the learning process more enjoyable and meaningful.
2. For teachers, the findings of this research can serve as a reference for teachers to apply Project-Based Learning (PjBL) using the Engineering Design Process (EDP) in science education. This approach encourages more active student participation and makes learning more relevant to real-life situations.

3. For another researchers, the findings of this research provide researchers with valuable data and insights on students' critical thinking skills and awareness through STEM project-based learning with Engineering Design Process (EDP) at junior high school level, serving as a potential reference for future research.

1.6 Scope of Research

This study is limited to several specific aspects in order to maintain focus and feasibility during the research implementations. These limitations are outlined as follows:

1. STEM learning model

   This study is limited to the use of STEM as a learning model that emphasizes real-life problem-solving through projects integrating science, technology, engineering, and mathematics. The implementation is based on the six stages proposed by Widodo (2021): identify the problem, think, design, create, test, and redesign. Other models of STEM learning model instruction are not included.

2. Engineering Design Process

   The engineering context in this study is structured using the EDP approach, which supports students in systematically solving problems. The stages adopted include: identifying the need or problem, researching the problem, sketching possible ideas, selecting the best solutions, designing and constructing a prototype, testing and evaluating the solution(s), and communicating the solution(s). This study does not incorporate other problem-solving frameworks or variations of the EDP beyond this structure.

3. STEM with Engineering Design Process

   The integration of STEM with EDP in this study is limited to classroom-based group projects involving the design and creation of a wind turbines project as a contextual representation of renewable energy problems. This combined model is applied only in the experimental class. The control class uses STEM without EDP. Other integrations of STEM with different approaches are not examined in this study.

4. Students' Renewable Energy Awareness

Students' awareness of renewable energy is measured using a Likert-scale questionnaire adapted from Kacan (2015). The instrument focuses only on self-reported indicators across five dimensions: awareness knowledge, environmental impact, policy and investment, attitude and opinion, and education and social responsibility. This awareness is measured before and after the intervention. The instrument does not assess long-term behavior, practical application, or in-depth environmental literacy beyond what is captured in the questionnaire.

5. Students' Critical Thinking Skills

The measurement of students' critical thinking skills in this study is limited to five indicators based on the rubric by Ennis & Weir (1985), as adopted by Ijirana et al., which include: strategies and tactics/determining actions, developing basic skills/observing, inferring/making and evaluating statements, providing further explanations/identifying assumptions, and providing elementary clarification/focusing questions. The assessment is carried out through open-ended essay questions related to the topic of renewable energy. This study does not include other 21st-century skills or higher-order thinking skills beyond these indicators. The measurement only covers pre- and post-test performance and does not assess the long-term retention or transferability of critical thinking skills to other contexts.

6. Renewable Energy Topic

Renewable energy is the science topic that was chosen in this research. Renewable energy is energy that comes from natural resources and it is free to use. It has several resources, such as solar, wind, water, biomass, and geothermal. In this research, the renewable energy topic will focus on wind energy, and the project is about a wind turbine project. This topic is intended for 8th junior high school students in Bandung with the Merdeka Curriculum.