CHAPTER I
INTRODUCTION

1.1. Research Background

Waste increases environmental problems and gets worse every day. According to the World Bank, Indonesia produces approximately 42 million tons of waste. This situation arises from the country's rapid population growth (Qonitan et al., 2021). In this scenario, Indonesia, a country with a typically growing population, will experience an increase in waste production. Due to its massive waste output, Indonesia consistently faces environmental issues. The air quality in the cities and the amount of trash in the streets and rivers are so bad that everyone must notice them. These problems must have many impacts for our today and future. However, the majority of Indonesia's waste management systems are still conventional and sustainable waste management methods are by no means the standard (Fatimah et al., 2020). This indicates that waste management in Indonesia still has room for improvement.

Anything other than waste produced in cities that is not liquid and is generated by individuals, families, small enterprises, or organizations is referred to a solid waste (SW) (Debrah et al., 2021). As the global population continues to increase, the worldwide production of solid waste is expected to rise accordingly, reaching 3.40 billion metric tons (MT) per year by 2050 (Khan et al., 2022). It’s obvious that more people would mean more waste. Therefore, rapid urbanization in Indonesia has led to numerous environmental issues, especially the problem of solid waste management (Wibisono et al., 2020). In 2019, solid waste generation reached 700,000 tons/year, followed by 679,000 tons/year in 2020 and 643,000 tons/year in 2021, with West Java, East Java, and Central Java producing the most solid waste (Gutama & Iresha, 2023). This production of solid waste significantly contributes to the pollution of air, water, and land. Furthermore, people often burn, bury, or dump their waste in parks, canals, rivers, and streets when they don't get their trash picked up (World Bank, 2020).

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Solid waste management is related to the Sustainable Development Goal for Responsible Consumption and Production (SDG 12). Solid waste management that is not carried out properly become a source of environmental pollution. When organic waste breaks down in landfills, it makes methane (CH_4), a greenhouse gas that could warm the earth. Burning waste also releases dangerous pollutants into the air, including fine particles, nitrogen oxides, and sulfur dioxide. These pollutants can negatively impact human health (Shovon et al., 2024). Pollution of the environment is not just a local problem; it's a worldwide problem that needs real solutions. Therefore, understanding the environmental pollution caused by solid waste is very important, especially for students as the generation that will make decisions related to sustainability in the future. Environmental pollution caused by poorly managed solid waste shows that students need to learn how the things they do every day affect the environment and become more aware of how important it is to manage waste properly.

However, students are not given enough experience for sustainability decision-making at school (Torsdottir et al., 2024). Previous study also states that students have a high concern for their environment, but they are rarely or never take sustainability actions (Permanasari & Dwi Pursitasari, 2021). To support the SDGs 12, we need to improve how we manage solid waste, which can be achieved through formal education and increased awareness (Debrah et al., 2021). With education, it encourages students to take action addressing sustainable waste issues and fosters their action competency and by introducing the subject of environmental pollution into education enables students to comprehend the effects of their actions on the environment while actively participating in tangible sustainability initiatives, such waste recycling and responsible waste management (Jumintono & Mohamad Rafizi bin Taha, 2022).

The ability to think critically and take action wisely that promotes sustainable development defined as action competency (Sass et al., 2020). Students' actions are about their willingness to act, especially in the case of sustainability. Sustainability action can be developed through hands-on projects addressing real-world issues. Allowing students to participate in decision-making processes

through thoughtful discussions about real-world challenging problems would develop sustainability competencies (Sass et al., 2021).

Research conducted in Germany found that students had an average level of understanding and action regarding sustainability (Braßler & Sprenger, 2021). In Indonesia, research done in Riau found that only 75.78% of the 180 students who took part in it were taking sustainable action (Ruslindawati et al., 2022). One of the reasons students don't take sustainable actions is that they haven't had enough practice making decisions about sustainability. The lacks of this experience can affect students' confidence, which is the best predictor of sustainability action. Students with strong knowledge of sustainability but if they lack confidence in their ability to act effectively, they may not take action (Oinonen et al., 2024). Another reason is because the majority of educational activities just focus on knowledge, memory, and reasoning (Safitri et al., 2024).

To help students build action, one of the most important ways is to give them the opportunity to solve real-world issues, especially those related to sustainability (Torsdottir, Olsson, & Sinnes, 2024). This can be implemented through the application of the Engineering Design Process (EDP). The engineering design process is a step-by-step decision-making process that utilizes science, math, and technical knowledge to develophe best possible solution (Linh & Huong, 2021). Students learn how to think and work like engineers by going through the engineering design process. This gives them hands-on experience that helps them improve their engineering design skills. It is not only about making things; it also teaches students how to think innovating, difficulties, and use math and science to deal with problems in the real world (Tipmontiane & Williams, 2021). Through the engineering design process, students will be able to address difficulties while taking responsibility for societal and environmental concerns in the future (Sen et al., 2021).

For secondary students, engineering design process is a successful model for STEM-integrated learning, as it fosters their scientific thinking (Tipmontiane & Williams, 2022). However, in Indonesia, university students are not equipped with enough design experience (Veza et al., 2021) and at the secondary school level is

still rarely used (Abdurrahman et al., 2023). This is because, unfortunately, high schools often lack sufficient support for engineering design, which makes it challenging to teach engineering effectively and consistentlyn secondary schools (Tipmontiane & Williams, 2021). As a result, this problem can lead to students in Indonesia having low engineering design skills. Students' engineering design skills can be affected by many factors, one of the factors is lack of engineering design at school such as hands-on activities to solve the problem by creating something. To develop students' engineering design skills, teachers can utilize ESD-STEM learning to encourage student engagement in hands-on activities,uch as designing and creating projects (Abdurrahman et al., 2023).

ESD, or Education for Sustainable Development, is a lifetime learning program that gives people the tools they need to build a sustainable future by integrating environmental issues, promoting sustainable economic growth, and building a fair society for everyone, both now and in the future (Lestari et al., 2024). ESD affects students' ability to take action for sustainable development and environmental learning (Olsson et al., 2022). As a result, ESD's goal is to help students gain the action competence they need for sustainable development. This includes the commitment, enthusiasm, knowledge, and self-efficacy to help solve SD challenges (Sass et al., 2020). ESD can be implemented variously, one of which is with the integration of STEM learning.

STEM is the integration of four disciplines (science, technology, engineering, and mathematics) into one class or lesson, and it is centered on the relationship between the subject and real-world problems (Rusmana et al., 2021). In an effort toward achieving sustainable development goals in education, specifically concerning sustainability challenges, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) supports STEM as an approach in the teaching and learning process of STEM-related subjects (García-González et al., 2020). According to Widodo, A. (2021), STEM has learning phases that should be followed. These phases include coming up with a problem, thinking about technological solutions, designing future technology, making technology products, testing those products, and improving technology through better initial design.

From these phases, STEM learning will help students develop their engineering skills, which are necessary for performing engineering design, the process of creating a system or component to meet specific needs (Rusmana et al., 2021).

STEM and ESD have similar common goals, especially when it comes to engaging students to work on real-world challenges (Fathurohman et al., 2023). Combining ESD with STEM helps students learn how to use scientific and mathematical principles to come up with new technological solutions. It also makes them think about how technology can be used in a way that is good for the environment and the community as a whole (Rahman et al., 2023). In Indonesian education, integrating STEM with ESD reveals significant benefits and improvement areas. In addition, using ESD-STEM learning in some Indonesian secondary schools has made students more interested, creative, and aware of the need for sustainable development (Aswirna et al., 2022).

ESD has often been used to raise awareness of sustainable development, especially when it comes to environmental issues like solid waste management. However, Debrah et al. (2021) examine the role of formal education in enhancing awareness of solid waste management; however, they do not address the use of Education for Sustainable Development (ESD) in STEM education to promote sustainable waste practices. One of the factors that might affect the implementation of ESD-STEM in Indonesia is that it has not been widely implemented in the classroom because not many teachers have a background in STEM learning for sustainability (Zuhaida et al., 2024).

On the other side, several new studies have started to look into ESD-STEM integration, but most of the focus is still on cognitive outcomes such as sustainability knowledge and awareness. For example, research by Puspha Annisa et al. (2024) examines STEM-ESD-based learning that focuses on the students' critical thinking and sustainability awareness, whereas this research emphasizes on improving students' engineering design skills and sustainability action. Engineering design skills are often taught along with STEM learning. For example, Hadistia et al. (2020) studied how to improve students' engineering design skills through STEM learning. Nevertheless, because of the importance of environmental

problems, mainly those involving solid waste, ESD needs to be integrated with STEM learning in order to better address sustainability issues with engineering design skills.

According to all of the explanations above, there hasn't been much research done on how to use solid waste management projects to improve students' engineering design skills and sustainability actions. Although some studies have conducted ESD or STEM learning, to combine both of them, enhancing engineering design skills and sustainability action in the context of solid waste management learning, especially at the junior high school level, is still rarely researched. To learn the causes, the effects, and the way to manage the waste to overcome the environmental issue, environmental pollution was chosen as a topic for the basic understanding to face real-life issues. As a result, the title of this study is "ESD-STEM Solid Waste Management Project to Enhance Students' Engineering Design Skills and Sustainability Actions in Learning Environmental Pollution."

1.2. Research Problem

According to the provided background, the research problem of this study is "How does the ESD-STEM solid waste management project enhance students' engineering design skills and sustainability action in learning environmental pollution?"

Derived from the research problem, the study attempts to investigate the following questions:

a. How is the profile of students' engineering design skills after implementing the ESD-STEM solid waste management project in learning environmental pollution?
b. How does the ESD-STEM solid waste management project affect students' sustainability action in learning environmental pollution?

1.3. Operational Definition

1. ESD-STEM Solid Waste Management Project

ESD-STEM Solid Waste Management Project is a STEM-based learning experience in which students carry out a solid waste management project to create technology products for sustainable development and address environmental challenges. The learning implementation is based on the STEM stages where students are given the opportunity to formulate the problems, think about the solutions, design, create, test, and redesign their technology product that can help to sort different types of solid waste, such as paper, plastic, metal, or glass. Thus, the product is like a trash bin with more than 1 section for each type of waste. The products utilize ESP32 with the help of sensors and motors. This project lets students improve their engineering design skills and sustainability action by providing the opportunities for students to think about the best solution to overcome the real-world problem, which is solid waste that is increasingly piling up and unsorted. In the end, the products made by students are useful to facilitate the next waste processing process as an effort to reduce environmental pollution.

2. Engineering Design Skill

Engineering design skill is the ability to conduct engineering design, which is the process of creating something that serves to fulfill particular needs. The assessment was carried out through the direct observation in the learning process and then evaluated using A Performance-Based Evaluation Rubric for Assessing and Enhancing Engineering Design Skills which consists of four phases, namely problem, solution, implementation, and process management. The rubric ranged from the lowest of 1 to the higher of 4. The data were analyzed by calculating the average score to show how good students' engineering design skills. Students' engineering design skill was assessed only after the implementation of ESD-STEM solid waste management project and only in the experimental class.

3. Sustainability Action

Sustainability action refers to the willingness and self-efficacy for contributing to sustainable development related to environmental issues. Students' sustainability action for dealing with environmental issues were measured using a questionnaire

that distribted as the pretest and posttest with a 4-point Likert scale. This questionnaire was adopted from the Environmental Citizenship Questionnaire (ECQ) with the indicators of past action, present action, future action, and comptenecies and considered the ESD Learning Goals and the data were analyzed using Mann-Whitney U test.

1.4. Research Objectives

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

a. To investigate the improvement of students' engineering design skills through the ESD-STEM solid waste management project in learning environmental pollution.
b. To investigate the improvement of students' sustainability action through the ESD-STEM solid waste management project in learning environmental pollution.

1.5. Research Benefit

1. For students, they can improve their sustainability actions and engineering design skills. Students are given the opportunity to contribute to solid waste management that they often encounter by participating in the project, so that they can gain new experiences through the ESD-STEM learning.
2. For teachers, this ESD-STEM project can be used as an idea for learning activities to enhance students' engineering design skills and sustainability actions related to environmental pollution.
3. For researchers, the study's findings provide data and information concerning students' sustainability action and engineering design skills with ESD-based STEM learning at the junior high school level, which may be applied as a reference in future research.

1.6. Scope of Research

This research focuses on the application of ESD-STEM to enhance students' engineering design skills and sustainability actions regarding solid waste

management on the topic of environmental pollution. Specifically, this research falls within the ESD and STEM areas because this research assesses changes in students' sustainability actions and assesses students' engineering design skills through integrative education, namely ESD-STEM, in the context of environmental pollution. The method of this research was a quasi-experiment by using the pretest-posttest non-equivalent control group design. This research used questionnaires, observations, and interviews to measure students' engineering design skills and sustainability action. In order to accurately measure all of the aspects of the variables that were being observed, the instruments included a questionnaire on responsible consumption and production as well as a performance-based evaluation rubric. Data were collected through questionnaires before and after learning, observations during the learning process, and interviews after the treatment was given. Quantitative data from the questionnaire were analyzed using statistical tests using IBM SPSS, and also descriptive calculations from rubric scoring. At the same time, qualitative data was analyzed based on the results of observations and interviews. The samples in this research were junior high school students in the seventh grade at a public school in Bandung.