

## Article

# Students' Engagement in Education as Sustainability: Implementing an Ethical Dilemma-STEAM Teaching Model in Chemistry Learning

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**Abstract:** This paper reports the results of a study on the implementation of the Ethical Dilemma STEAM Teaching Model in secondary schools in Jakarta, Indonesia. This interdisciplinary curriculum approach employed 'ethical dilemma story pedagogy' in a STEAM education project designed to engage students in values-based chemistry learning. Drawing on the arts, specially written ethical dilemma stories posing real-world environmental problems engaged students in exploring their value systems. Students reflected on the pros and cons of ethical dilemmas related to the everyday use of artificial fertilizers, disposal of used cooking oil and detergent waste, and environmental pollution caused by plastic waste. The purpose of the study was to investigate the potential of the Ethical Dilemma STEAM Teaching Model to empower Indonesian secondary school students with both chemistry knowledge and transdisciplinary capabilities for resolving environmental problems. The researchers conducted an interpretive case study of four high-school chemistry classes to understand students' learning experiences and outcomes. Data were obtained from students' reflective journals, semi-structured interviews, and classroom observations. The results demonstrate that students engaged in deep chemistry learning while simultaneously developing critical reflective social thinking, collaborative decision-making skills, and increased awareness of the need to protect the environment in order to support sustainable development. The study revealed that chemistry education can play a strategic role through ethical values learning in empowering students to become agents of change for environmental sustainability. Further research is warranted into the efficacy of the Ethical Dilemma STEAM Teaching Model for empowering students in sustainability education across a broad range of science-related topics and sociocultural contexts.



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**Keywords:** ethical dilemma stories; STEAM education; chemistry learning; sustainability education; values learning

## 1. Introduction

Education is key to creating a sustainable environment through the development of human resources. Therefore, educators play a crucial role in promoting sustainability education [1] and for providing education related to the environment [2] so that students appreciate all available resources to support their survival [3]. According to Morris [3], awareness is the starting point for the reconceptualization of cognition which is closely influenced by the nature of the environment, so educators must design and organize learning to support sustainability education.

The current education curriculum in Indonesia, known as the '2013 Curriculum', develops knowledge and skills with an emphasis on character building through the development of individual ethics and values. The increased scope of the curriculum aims has resulted in various impacts on its implementation, such as a revision of curriculum

development and teacher competencies and the related assessment system, which includes the administration of chemistry education. The resulting holistic curriculum focus requires a paradigm shift from both teachers and students. Teachers must adapt the curriculum to provide opportunities for transformative and empowering learning as well as developing students' skills and knowledge.

One way to empower students in sustainability education is to implement values-based learning such as 'ethical dilemma story pedagogy' (EDSP) with ethical dilemma stories as learning media. Ethical dilemma stories involve students in real-life situations [4] where they are encouraged to make decisions about environmental conditions that could lead to adverse outcomes [5]. EDSP requires individuals to reflect on issues and explain decisions based on their personal values [6]. Additionally, ethical dilemma stories engage students in social learning through group discussions and in emotional learning through the argumentation of various opinions and views [4]. Ethical dilemma stories were developed with reference to relevant environmental contexts in several countries and include 'the mining dilemma', 'the rice-fish dilemma', 'the nuclear power dilemma', and 'the climate change dilemma' [7]. Previous research indicates that engaging students in ethical dilemma pedagogy through case studies helps broaden their conceptual understanding, empathy enhancement, and commitment to social justice principles [8]. In an Indonesian context, the implementation of EDSP has been shown to increase learning motivation, responsibility, curiosity, and the courage to debate issues [9]. Previous studies have also revealed that EDSP develops a student's ability to collaborate, reflect on their values and increase their awareness of environmental and social issues related to chemistry learning [10]. Moreover, integrating EDSP with chemistry empowers students to actively engage in their learning. Meaningful learning opportunities related to real-life events [11] develop students' chemical literacy whilst teachers play a supporting role [12].

STEAM education promotes transformative, integrated learning that provides students with unique interdisciplinary curricular and pedagogical opportunities to solve problems that occur in their environment. STEAM is a relatively new educational paradigm that emphasizes creative, interdisciplinary, contextual, problem- or project-based teaching and learning [13]. STEAM is a derivative of STEM; the addition of 'A' representing the arts encourages collaboration, creativity, and innovation [14,15], as well as developing 21st-century skills [16] such as increased learning engagement and motivation [17–19], communication and collaboration [20,21], critical thinking [22–24], and creative thinking [17,19,24–26].

The research addressed in this paper integrated EDSP with a STEAM education project to create the 'Ethical Dilemma STEAM Teaching Model'. This model provides opportunities and challenges for integrating the values of sustainability education and transformative learning. Conceptual understanding and skills from various disciplines are needed to solve complex problems in real life [27]. Therefore, this study focused on integrating EDSP with a STEAM education chemistry project to engage students in sustainability education. A key goal was to enhance the relevance of chemistry in students' everyday lives, thus engaging them in deep learning.

## 2. Literature Review

### 2.1. Chemistry Education and Sustainability

Sustainability has become an important issue in political, economic, social, and environmental forums since the early 2000s [28]. 'Sustainability' and 'sustainable development' emerged from a United Nations conference in Rio De Janeiro in 1992. Sustainability is an essential key to development which encourages accelerated development that minimizes or removes adverse impacts on the environment [28]. These two concepts, sustainability and sustainable development, have been widely discussed in various disciplines in the last decade, especially in education [29].

The role of education in environmental sustainability is known by various terms. Chansomsak and Vale [30] describe sustainability education as having the same goals and objectives as environmental education. The term environmental education first appeared

in 1975 at a UNESCO meeting in Belgrade [31]. Environmental education plays a vital role in building responsibility and directly empowers students to think critically, collaborate and participate through individual actions to maintain and improve the quality of physical and aesthetic environments [31,32]. In the Indonesian context, environmental education is integrated into the curriculum as part of science teaching. Education plays an essential role in building awareness of the need to preserve the environment [33] and by changing individual perspectives from viewing the Earth as a resource that can be exploited to one that must be maintained [3].

To understand the role of education in raising awareness of sustainability, Sterling [34] defines three forms of sustainability education: ‘education about sustainability’, ‘education for sustainability’, and ‘education as sustainability’. Education about sustainability focuses on curriculum content, education for sustainability emphasizes purpose, and education as sustainability means empowerment and action. Thus, sustainability education is assessed as a dynamic, contextual, inclusive, integrated system that increases individual concern for environmental sustainability [34]. Therefore, to achieve a holistic environmental education process, teachers must include education as sustainability, not just education about/for sustainability. It is essential to empower teachers and students to take action in their daily lives for a better environment in the future [35], not just teach subjects or include topics about the environment.

Sustainability education challenges professionals and academics to integrate sustainability practices into all disciplines [36]. Sustainability science is known as a meta discipline because it requires the integration of various disciplines to design holistic solutions to solve complex global problems [37]. Chemistry contributes significantly to sustainable development strategies [38]. Chemistry is a branch of science used to understand natural events through systematic methods. Chemistry is the study of matter, including its composition, properties, changes, and energy accompanying these changes [39]. Brady [40] defines chemistry as a science that studies the matter in the universe, the interactions between them, and the energy changes associated with or caused by natural changes. According to Taber [41], chemistry provides learners with an understanding of what is happening in the surrounding environment because chemistry studies the structure of a material. Chemistry education promotes new knowledge about exciting and useful experimental phenomena and activities for understanding the world scientifically. Therefore, sustainability in chemistry education is essential for raising students’ awareness and encouraging their contributions in overcoming complex problems [42,43].

## 2.2. Ethical Dilemma STEAM Teaching Model

The Ethical Dilemma STEAM Teaching Model was developed by integrating EDSP with a STEAM education project. EDSP is a pedagogical method designed to engage students in values-based, transformative learning by using ethical dilemma stories [5]. Ethically confusing issues force students to engage in reflective and critical thinking to find appropriate solutions [44,45]. The process of reflection and interaction with peers enables students to change by adapting existing values and building new values [4]. EDSP actively transforms learners by encouraging them to think about their pre-existing beliefs and biases and promoting their active participation in self-reflection and social-emotional learning by proposing relevant solutions [4]. In this study, students were encouraged to construct their values through the medium of ethical dilemma stories told by the teachers who played a vital role as facilitators rather than imposing their own values. A basic assumption of EDSP, as a constructivist learning style [46], is that the learning process becomes a reference for values-based learning based on Piaget’s constructivist theory that values cannot be taught explicitly but must be developed by the students.

Ethical dilemma stories present students with scenarios involving a range of characters and plots in an ethical dilemma. Students are motivated to understand the cases in the story, make decisions and solve the problems [4]. Ideally, ethical dilemma stories include concepts relevant to the students’ lived reality. Settelmaier [45] states that ethical dilemma stories

can be presented in various forms, including a summary of problematic situations, role-plays, films, and story-telling. Thus EDSP provides an engaging, authentic, investigative, and meaningful learning experience for students [47]. An ethical dilemma story does not present a final solution; it encourages students to reflect, think, and prolong learning by involving conceptual understanding through a range of disciplines, such as chemistry, physics, biology, and mathematics concepts, to engage deeply with the story to arrive at effective solutions. EDSP does not aim to replace content-based science education. It aims to improve the quality and relevance of science education to modern students by including a values-focused approach to learning the content. Through the EDSP process, students become actively engaged in values-based learning in various ways: (1) students are encouraged to think critically about the ethical dilemmas presented, (2) students are encouraged to self-reflect and make decisions on the ethical dilemma cases presented, (3) students engage in social learning by discussing with peers, (4) emotional learning is encouraged through discussion and by enhancing tolerance when students encounter different views, and (5) students are encouraged to collaboratively solve problems presented in the dilemma stories [4].

Over the last decade, STEAM education has become the subject of increasing interest in scientific studies and education [48]. The approach is based on the understanding that solving complex, real-world problems requires knowledge and skills from various disciplines [27], meaning that interdisciplinary skills are needed to solve complex contextual problems [49,50]. STEAM education is an expansion of STEM, a multidisciplinary learning approach that emphasizes the importance of developing problem-solving skills so that students can compete in an era of increased globalization and be ready to face future challenges [51]. The integration of 'A', the arts, into STEM encourages collaboration and develops innovation [15]. The role of arts in STEAM promotes creative pedagogical practices [52], increases motivation and learning effectiveness [53], maintains a balance of science and technology, and creates interdisciplinary learning that is more inclusive and integrative [18]. STEAM education is a transformative approach to the students' non-material world that increases morale and ethical awareness in support of sustainable development [54].

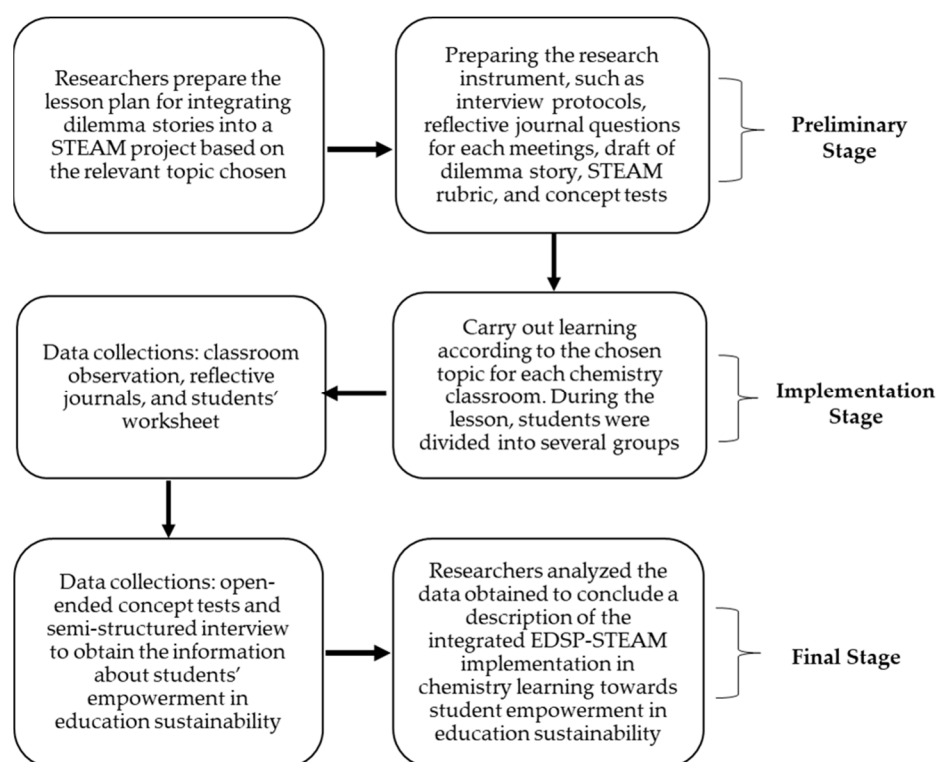
A STEAM approach is a hands-on, collaborative study of real-life problems that encourages students to acquire procedural skills [55,56]. In practice, a STEAM approach can be implemented through project-based learning (PjBL) [57,58]. PjBL has five dimensions: content integration, problem-centered, inquiry-based, design-based, and cooperative learning [59]. The use of PjBL to implement a STEAM approach encourages an in-depth understanding of content as well as promoting development of skills such as communication, identification, and problem-solving [60], increased learning motivation [18,61,62], and creative and moral/ethical awareness to empower students in sustainability practices [63].

### 3. Method

#### 3.1. Research Design

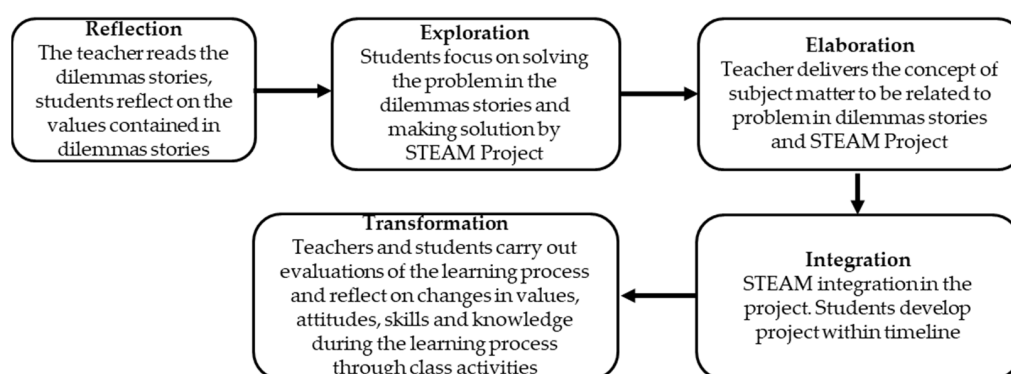
The purpose of this study was to answer the research question: what is the potential of the Ethical Dilemma STEAM Teaching Model to empower Indonesian secondary school students with both chemistry knowledge and transdisciplinary capabilities with which to resolve environmental problems? Thus, the goal was to investigate how well students can respond to this innovative teaching and learning approach. In order to achieve this, the research was designed as an interpretive case study whose constructivist epistemology enables researchers to understand participants' lived experiences of a social phenomenon [64,65]. Data were collected from semi-structured interviewing, students' reflective journaling, and extensive classroom observations. The study was conducted in four high schools in Jakarta, with a total of 155 participants, consisting of school A (36 students in grade 10), school B (36 students in grade 11), school C (36 students in grade 11), and school D (47 students in grade 12). Informed consent was obtained from students who volunteered to be involved in data collection and analysis. The research was conducted

in three stages—the preliminary stage, the implementation stage, and the final stage—as shown in Figure 1.



**Figure 1.** Research flow and data collection.

Four topics, appropriate to the class level of the students, were selected from the chemistry curriculum: oxidation-reduction reactions (school A), buffer solutions (school B), acids and bases (school C), and polymers (school D). The implementation of the Ethical Dilemma STEAM Teaching Model consisted of five stages: reflection, exploration, elaboration, integration, transformation, as shown in Figure 2.



**Figure 2.** Ethical Dilemma STEAM Teaching Model.

The use of ethical dilemma stories in the learning process encouraged students to find solutions to the dilemmas presented in a STEAM education project. In relation to chemistry learning, Table 1 shows how elements of chemistry were implemented through a STEAM approach. In school A, students developed an aromatic candle and soap project to solve the used cooking oil ethical dilemma. In school B, the buffer solution was a fundamental concept in developing a hydroponic plant project from the ethical dilemma of artificial fertilizers. At school C, students were encouraged to be creative in making

wastewater treatments for solving the problem of detergent waste that often occurs in their neighborhood. Meanwhile, at school D, students developed biodegradable plastic with various natural goods as the primary material to reduce the use of plastic waste that is difficult to decompose in the environment. Table 1 illustrates the linkages of the ethical dilemma stories presented in this study with the Indonesia chemistry curricula.

**Table 1.** Linkage of ethical dilemma stories with Indonesian chemistry curricula.

Issue	Chemistry Topic	Ethical Dilemma Story Description	Outcomes
Used cooking oil dilemma	Reduction and Oxidation	This story describes a student who is in a dilemma because his parents, who own a 'crispy banana' snack business, cheat by using used cooking oil in the process of frying their product and throwing it directly on the ground. The student understands that the oxidation reaction resulting from the frying process is bad for health if consumed and produces harmful compounds. Therefore, he felt he was responsible for telling his parents about it. However, another ethical dilemma arises: if the oil used is always fresh, then what action should be taken? Increase the price or reduce the size of the product?	Students understand the concept of redox reaction and apply it to their daily lives
Artificial fertilizers dilemma	Buffer Solution	This tells the story of a farmer who grows sugar cane and needs ZA fertilizer so that his plants can grow well. The farmer's son is a student studying buffer solutions at school. The student has learned various buffer solutions and their good and bad effects. Later, the student realized that the fertilizer his father used would harm his father's farm in the future. However, the fertilizer is beneficial for the growth of sugar cane, and if it is replaced, it is feared that it will reduce sugarcane production from his father's farm.	Students understand the function of buffer solutions in human life
Detergent waste dilemma	Acid and Base	A student is faced with economic problems because his father, as the breadwinner of his family, has died. His mother, who started a business as a laundry worker to establish a laundry business, did not realize that the detergent waste harms the river's biota where the waste is disposed. The student who understands the impact of alkaline fluids on living ecosystems must think about how to help his mother's business not to pollute the environment. Various issues must be considered for environmental safety and economic calculations in his mother's business.	Students explore the application of acid and bases in everyday life and apply their conceptual understanding to solve the environmental problem
Plastic dilemma	Polymer	This story describes a father who worked in a plastics factory for 25 years. The story confronts a student in an ethical dilemma of a whale that died and was stranded on Wakatobi Island. After being identified, it turned out that the whale died because it was poisoned by plastic. Thus, policies to reduce plastic waste are widely encouraged, even to the point of banning plastics. The elderly father finds it difficult to find another job, but on the other hand, the son understands the impact of plastics on the environment and the living things in it. Therefore, how does he solve it?	Students analyze the problem related to polymer topics and use their knowledge to develop biodegradable plastic, which is environmentally friendly.

### 3.2. Data Collection

Data were collected from semi-structured interviewing, students' reflective journals, and classroom observations throughout the process of implementing the integrated EDSP and STEAM education project. The students were closely observed during the learning process, and information was obtained on their engagement with environmental issues and their problem solutions. In addition, two external observers assisted the researchers to witness every student-student and student-teacher communication when applying EDSP integration into the STEAM education project in chemistry learning. During interviews, students were asked several questions designed to explore their conceptual understanding, feelings, and learning difficulties. Examples of these questions:

- Cilacap Regency is one of the largest iron ore-producing areas in Indonesia. An extraction process is needed to obtain ferrous metals. Iron is extracted from iron ore containing the compound hematite ( $\text{Fe}_2\text{O}_3$ ). The extraction process is carried out in a furnace, where carbon monoxide (CO) gas will react with hematite compounds. This reaction will produce molten iron (Fe) and carbon dioxide gas ( $\text{CO}_2$ ). Based on this statement, can you explain the chemical reaction during the iron extraction process? Is it a redox reaction?
- What things did you like and dislike during the learning process today?
- Detergent is a commercial product used to remove stains from clothes. Detergent is an alkaline salt because it contains a weak acid, namely phosphoric acid ( $\text{H}_3\text{PO}_4$ ), and a strong base, namely sodium hydroxide (NaOH). Explain why  $\text{H}_3\text{PO}_4$  is categorized as acid and NaOH is categorized as a base!
- What obstacles did you face in the trial process of making biodegradable plastics, and how did you overcome these problems?

After the learning activities ended, semi-structured interviews were conducted with students individually and in groups through focus group discussions. The purpose of the interviews was to obtain more in-depth information from teachers and students regarding their responses to the process of the EDSP and STEAM integrated project and to measure the degree of student empowerment in sustainability education. The following are examples of interview questions posed to students.

- Many food vendors still use cooking oil for frying; what is your response to this? (School A).
- Based on the learning activities you completed, could you explain the concept of the buffer solution that you applied? (School B).
- If acidic liquid waste is directly discharged into the river, how will it affect the health of the people who use river water as a source of water for bathing and washing clothes? (School C).
- What action do you think should be taken to prevent the negative impact of plastic as in the plastic waste dilemma? (School D).

### 3.3. Data Analysis

Data analysis was carried out in 3 stages: data reduction, data display, and concluding/verification [66]. The data obtained from various sources was reduced by categorizing the findings (coding) from appropriate data. The data were then presented in a matrix table based on the categorization. Implications of the implementation of the Ethical Dilemma STEAM Teaching Model in chemistry on student empowerment in sustainability were then analyzed.

'Credibility criteria' of interpretive research were used to verify the data for inferring conclusions, including prolonged engagement, persistent observation, progressive subjectivity, and member checking [66] to test trustworthiness [64]. Prolonged engagement was carried out for the duration of the research to understand the context of the study, explore students' involvement, and implement the integration of ethical dilemmas stories into the STEAM education project for a certain period of each chemistry classroom. At the same

time, persistent observation was carried out by two observers to explore various in-depth phenomena and was assisted by those who analyzed the learning process. Progressive subjectivity was carried out to monitor the study results based on the researchers' notes obtained during the study based on students' empowerment in sustainability education, and member checking was performed to ensure accuracy by confirming research subjects' ambiguous data. All hard copies and soft files of data were kept confidential to ensure student confidentiality.

#### 4. Results and Discussion

This section reports four categories of findings followed by a discussion to ascertain the degree of student engagement with the ethical dilemma stories and the STEAM project.

##### 4.1. Values Reflection in Deep Chemistry Learning

The integration of contextual problems presented in ethical dilemma stories enabled students to see the relevance of chemical concepts to everyday life. At the values reflection and problem-solving stages, students were directly involved in emotional learning through a dilemma story. Students' active engagement in their learning is demonstrated in the following transcripts.

*"Students try to connect the conflicts that occur with real-life through the issues raised in the dilemma story. Students understand that waste cooking oil can cause environmental damage. Therefore, they argue the importance of utilizing the waste to minimize the impact. In addition, students understand chemistry related to the physical change process of used cooking oil caused by oxidation reactions. So that students conclude the dangers of used cooking oil if used continuously on human health." (Classroom Observation, School A, 29 January 2020)*

*"Students relate the phenomena in the dilemma story to their daily lives by understanding the impact of detergent waste being dumped directly into the river. Students understand that alkaline detergent waste can disrupt the pH balance of the water, which causes the death of many fish in the river. In addition, students argued that the foam from detergent waste on the surface of the river can block sunlight from entering the riverbed so that aquatic plants cannot photosynthesize." (Classroom Observation, School C, 7 January 2019)*

The use of ethical dilemma stories with a STEAM approach encouraged students to actively analyze, collaborate, evaluate and solve problems. The process provided opportunities for students to integrate their prior knowledge with newly learned information to solve a problem [67,68]. Direct student involvement in the learning process helped students to gain a deeper understanding of the curriculum content [69,70]. Students who have a deep knowledge of subject matter can apply it to context-specific problems and scenarios that require critical evaluation [71]. In this study, students gained a new understanding of the term oxidation, which is one of the redox concepts, through phenomena that occur in real life. The emphasis on contextual-based learning by applying ethical dilemmas stories can stimulate students to reflect on the values of the content, whereby learning will be more meaningful [72].

*"Learning by integrating dilemma story is a new thing for me, and it is an exciting thing. Moreover, when making hydroponic plants, we are challenged to practice and apply the understanding of buffer solutions directly." (Reflective Journal of Student 6, School B, 4 March 2020)*

*"It is an exciting learning experience for me and fits into the current curriculum, encouraging me to be more active in the learning process. The activity of making projects inspired me to use the understanding of chemistry that was learned and learned to integrate technology, engineering, and mathematics. Learning becomes more interesting because the arts are combined in it." (Reflective Journal of Student 5, School C, 23 January 2019)*



The above reflection shows that the ethical dilemma stories and STEAM project promoted student engagement by providing a rich learning experience for students. EDSP provides opportunities for students to develop problem-solving skills that increase their involvement in learning through discussion that leads to decision-making [4]. STEAM generates meaningful learning through project development related to each of the represented disciplines. Students are challenged to work in groups to solve problems, test ideas, and present the results to an audience. By doing so, students' motivation and involvement in their learning increases [73].

#### 4.2. Critical Social Thinking

A 21st-century chemistry curriculum should involve approaches to learning that help students develop the skills needed to be competitive in the 21st century. A project approach that integrates EDSP with STEAM fosters students' thinking skills, as demonstrated by the following recorded classroom observations.

*Student 35: According to our group, using ZA fertilizer is beneficial for plants that cannot grow in alkaline pH; it can be lowered to the pH needed by the plant. But if ZA fertilizer is used in excess, the soil pH will become acidic and exceed the soil's acid limit. So the ground will become very acidic, inhibit plant growth, and reduce soil quality; thus, it will damage the environment. Therefore, I chose not to use ZA fertilizer because it has side effects.*

*Student 10: According to my group, if ZA fertilizer is an alternative route to lower the pH of the soil from alkaline to acidic and then maintain it, then use ZA fertilizer is needed to the required level.*

*Student 31: We disagree with the opinion of student 10. It is better to use more environmentally friendly fertilizers.*

*Student 21: If the land is already damaged, we should look for new ground to plant it.*

*Student 10: In our opinion, if it is already damaged, it won't be easy to restore the soil pH, even though we must meet our daily needs. If the condition is damaged, we have to look for alternatives to farming with non-soil media, such as hydroponics; I already did it in my house.*

*(Classroom Observation, School B, 24 April 2020)*

The above observations, made during class discussion, illustrate that students already had sound conceptual knowledge. The aim of the discussion was to determine the best solution to the problems highlighted in the ethical dilemma story. The students were encouraged to hone their thinking skills by analyzing, evaluating, and organizing information so that they could predict appropriate actions and reflect on them [74].

Contextual problems raised in the ethical dilemma story encouraged students to use critical thinking to identify issues and follow the inquiry process to make a conceptual analysis of the issues involved. Reasonable arguments enabled the students to understand the facts posed by the dilemma [75].

*"Direct disposal of acid waste from the laboratory will disrupt the composition of the soil and cause soil pH to become unbalanced, so the plants wither. If any plants die, the oxygen supply will decrease, and it also causes erosion." (Reflective Journal of Student 14, School C, 7 January 2019)*

The data suggest that students were able to identify problems and explain the effects of issues by discussing relevant information. They understood the causes and consequences of problems and could provide solutions. Therefore, the learning process needs to provide opportunities for active learning to explore new situations, answer questions, and solve real problems [76].

Current chemistry education is focused on shaping understanding of concepts and applying them in real situations in everyday life. The integration of EDSP into a STEAM education project can develop students' higher-order thinking skills as an aspect of chemical

literacy [11] by carrying out scientific investigations, generalizing findings, and using knowledge to explain phenomena in other fields, such as ‘earth science’ and ‘biological sciences’ [77].

#### 4.3. Collaborative Decision-Making

Learning that involves ethical dilemmas challenges students’ emotional intelligence, especially their willingness to consider other (sometimes conflicting) perspectives and ideas when collaborating to find a viable solution [78]. Students reported that the problem-solving activity in relation to the ethical dilemma story encouraged them to voice their opinions. Interaction between the students when sharing information provided an opportunity for them to learn to listen and accept each other’s opinions and afforded additional insight.

*“In solving the problems in the dilemma story, we share opinions according to each other’s perspectives. Until we finally made a decision together.” (Student 35 interview, School B, 21 April 2020)*

*Teacher: Can you tell me about the cooperation among members in your group in conducting discussions?*

*Student 14: Communication between students in my group is getting better. At first, many did not dare to have an opinion. But with the problems in the story, all the members are braver to share ideas. So, with dilemma stories, learning becomes more enthusiastic. (Interview of Student 14, School B, 22 April 2020)*

*In my opinion, this learning is quite fun because, in addition to learning about concepts, we are also trained to think more broadly through exchanging information in discussions to broaden our horizons. The activity of changing information makes communication with friends better. So that collaboration to produce projects will also be better. (Reflective Journal of Student 10, School A, 4 March 2020)*

The use of EDSP in this study encouraged students to reflect on their values both individually and in groups so that the exchange of ideas could provide the best solution to the problem. Taylor and Williams [79] refer to the process as ‘open and critical discourse’, which allows students to reflect on and evaluate their thoughts in comparison to other opinions so as to choose the most effective solution. These findings align with research conducted by Rahmawati et al. [12] that using ethical dilemma stories to teach chemistry encourages students to solve problems individually and in groups, where collaborating with other students is an essential practice.

Collaboration is necessary when students are faced with the contextual issues in ethical dilemma stories that challenge them to develop a project to address the dilemma. Communication and collaboration are key to achieving success in completing the projects.

*“I am happy to work with my team because we complement each other by reminding and assisting in evaluating each experiment in making biodegradable plastics.” (Reflective Journal of Student 12, School D, 22 February 2019)*

The project-making activities enabled students to actively participate and express themselves while also reaping the benefits of team collaboration [80]. This finding aligns with the vision and mission of project-based learning, which emphasizes student-centered learning and professional collaboration [81]. Throughout the process, it is the role of the teacher to promote independence and involve students directly to maintain motivation.

#### 4.4. Awareness of Environmental Values for Sustainability

Learning chemistry via ethical dilemma stories provides space for students to reflect on their values throughout the process. EDSP develops students’ efficacy as agents of change focused on maintaining a sustainable environment. The following statements indicate that students used creative thinking skills to preserve the principles of environmental justice for sustainable development [65].

*Teacher: What do you use to purify the used cooking oil?*

*Student 4: We use dry banana peels.*

*Teacher: Why do you use these materials?*

*Student 4: To reduce banana peel waste because it can act as a promising adsorbent besides charcoal.*

*(Teacher's Notes, School A, 5 February 2020)*

Students could express the principle of usefully reusing items. Students used banana peel as an adsorbent to improve the quality of consumable oil, as reported by Rengga et al. [82], that banana peel can be used to adsorb impurities in cooking oil, and activated charcoal banana peel can reduce the peroxide value of used cooking oil. Results indicate that students were encouraged to take positive actions when they had an opportunity to respond to environmental problems. An emerging environmental attitude is a core principle of environmental awareness [83]. The implications of integrating EDSP and STEAM in honing students' concern for the environment are demonstrated in the responses below.

*Teacher: We still need detergent even though we know that the waste can harm the environment. What do you think?*

*Student 25: It is undeniable that we need detergent, but we must have awareness about the dangers of waste. We must also take the initiative to manage the waste before it is disposed of, such as making tools to neutralize pH so that it is not harmful to the environment by using natural materials.*

*Teacher: Currently, many detergent advertisements promise many advantages, such as producing a lot of foam, quickly cleaning stains, and giving a fragrant smell. How do you respond to that?*

*Student 25: We have to be able to analyze the content first. In my opinion, it is better to use a detergent that contains LAS (Linear Alkyl Sulfonate) so that the foam is not too much. In addition, it is also important to make tools to manage the waste so that it does not become a pollutant in the environment.*

*(Interview of Student 25, School C, 28 January 2019)*

Environmental awareness is reflected in students' willingness to participate in environmental activities to develop their understanding of human activities that cause poor ecological quality. Other interviews showed that values-based learning encouraged students to be curious by creating action steps to manifest solutions to problems.

*Teacher: How do you propose to make biodegradable plastic? Did you know about it before?*

*Student 15: When we read the story about the plastic waste dilemma, I looked for information from the internet, and I thought that biodegradable plastic was the best solution. This type of plastic is environmentally friendly because it can be decomposed quickly in the environment. If people widely use bioplastics we can overcome the waste problem in Indonesia.*

*(Interview of Student 15, School D, 12 March 2019)*

Awareness of the importance of reducing plastic waste indicated that students felt they had a moral responsibility to protect the environment by taking real action. This finding aligns with results from Taylor and Taylor [84] that EDSP develops concern for the environment through decision-making steps based on students' scientific knowledge. The study exposes the role of education in changing students' perspectives and encouraging them to commit to reducing environmental damage caused by humans [85]. Therefore, the integration of EDSP and STEAM to create a project can be a promising alternative in providing education for changing students' perspectives in utilizing natural resources to maintain their sustainability.

## 5. Conclusions

This interpretive case study has demonstrated that the Ethical Dilemma STEAM Teaching Model, which integrates ethical dilemma story pedagogy with an interdisciplinary STEAM project, can empower Indonesian secondary school students with deep chemistry learning and transdisciplinary capabilities for resolving local environmental problems.

In particular, the results illustrate how students in four schools engaged successfully in values reflection, critical social thinking, and collaborative decision-making to design promising sustainability solutions to ethical dilemmas afflicting their local environments. These outcomes evidence students' ethical awareness of the importance of ensuring human well-being and sustainability of the natural environment.

The results add to the evidence supporting the role of STEAM education for developing students' scientific understanding of critical social issues, especially ethical dilemmas, and key transdisciplinary abilities for helping to resolve them. These advanced 21st-century attributes are important for students to graduate as socially responsible citizens for whom sustainability thinking is an essential part of their social actions at home, at work, and in their communities.

Because this was a case study of students in four secondary schools in Jakarta, Indonesia, the results are limited to this sociocultural context. Nevertheless, this study has demonstrated that further research is warranted into the efficacy of the Ethical Dilemma STEAM Teaching Model for empowering students in sustainability education across a broad range of science-related topics and sociocultural contexts.

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