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ASSESSING EDUCATION FOR SUSTAINABLE DEVELOPMENT (ESD) COMPETENCIES AND ENVIRONMENTAL EMPATHY IN DISASTER AND ENVIRONMENT KNOWLEDGE TO SUPPORT SDGs 2030

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ABSTRACT

Education for Sustainable Development (ESD) plays a crucial role in achieving the Sustainable Development Goals (SDGs) 2030 by promoting the acquisition of understanding, knowledge, and skills. This study aims to assess students' Education for Sustainable Development (ESD) competencies and examine the correlation between ESD competency and students' environmental empathy in Disaster and Environmental Knowledge at Universitas Syiah Kuala. This study employed a correlation research method with quantitative and qualitative approaches using random sampling techniques. The random sampling method was used to select 339 participants with a 95% confidence level. Data were collected using an ESD competency test, an environmental empathy questionnaire, and interviews. Data analysis was performed using the Pearson product-moment correlation technique. The analysis results show that the average score for students' systems thinking competency was 73.67% (good category), and students' critical thinking competence was 71.64% (adequate category). Statistical analysis shows a significant positive correlation between ESD competency and environmental empathy (r = 0.301), indicating that ESD competency explains 31.1% of the variance in environmental empathy. Therefore, it can be concluded that ESD competency is positively related to environmental empathy, though with a low level of correlation. This study provides valuable insights for universities and stakeholders in designing more effective ESD programs to promote sustainable development, especially goals 4 (quality education) and 13 (climate action).

Keywords: education for sustainable development; disaster education; competency; empathy; environmental knowledge

INTRODUCTION

In the era of globalization, environmental challenges have become increasingly complex and require a holistic approach to developing effective and sustainable solutions. The Sustainable Development Goals (SDGs) 2030, initiated by the United Nations, is a global framework for achieving social, economic, and environmental well-being (Tamsma & Costongs, 2018; Mensah, 2019; Carlsen & Bruggemann, 2022). A key pillar of the SDGs is sustainable environmental management, encompassing efforts to reduce greenhouse gas emissions, conserve biodiversity, and manage natural resources responsibly (Ladan, 2018; Khoshnava et al., 2019). Education plays a key role in achieving these goals, especially through the framework of Education for Sustainable Development (ESD) (García-Feijoo et al., 2020; Shulla et al., 2020).

ESD aims to provide individuals with the knowledge, skills, values, and attitudes needed to

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tackle environmental issues and support sustainable development (Agbedahin, 2019; Kioupi & Voulvoulis, 2019). It is also a key to achieving the SDGs by fostering a comprehensive understanding of global environmental issues and shaping attitudes, values, and behaviors related to society, the economy, and the environment (UNESCO, 2017; Rahman et al., 2019; Novidsa et al., 2020). As agents of change, students are expected to develop competencies in ESD and exhibit high levels of environmental empathy to support the 2030 SDGs agenda (Giangrande et al., 2019; Velempini, 2025).

Achieving these goals requires the development of specific competencies. According to UNESCO (2017), there are eight essential competencies for sustainable development: systems thinking, anticipatory, normative, strategic, collaboration, critical thinking, self-awareness, and integrated problem-solving competencies. These competencies are transversal, cross-functional, and applicable to all SDGs. Furthermore, these competencies are also interdisciplinary, allowing students to make connections between various SDG goals (Lozano et al., 2022; Fleaca et al., 2023; Podgórska & Zdonek, 2024).

Education must empower individuals to observe the environment and engage in critical and systems thinking to foster sustainable awareness. Systems thinking competency involves analyzing problems comprehensively by considering all interrelated factors, thus enabling sustainable decision-making. In the context of ESD, it facilitates the development of solutions to sustainable development issues by considering other supporting aspects. In addition to systems thinking competency, an important competency in ESD is critical thinking competency. Critical thinking competency equips individuals to address issues effectively, sharpens analytical skills, and generate practical solutions (Ahmad et al., 2023)

This study focuses on these two competencies, which is a limitation because systems thinking is a vital competency in education for sustainable development, enabling students to grasp the complexity and interconnectedness of natural, social, and economic systems (Molderez & Ceulemans, 2018; Schuler et al., 2018). Meanwhile, critical thinking is the key to all competencies, which is fundamental to 21st-century education (Kusumoto, 2018; Halim, 2022). Achieving a sustainable future requires incorporating critical thinking into environmental education because critical thinking is essential to providing individuals with the skills and knowledge needed to address complex environmental problems (Shutaleva, 2023).

ESD can also play an important role in fostering empathy by promoting awareness of global issues and fostering deep understanding. Developing empathy is also a priority in educational programs aimed at character development (Stavroulia & Lanitis, 2019; Goldstein & Michaels, 2021; Supriatno et al, 2023). Environmental empathy refers to the ability to feel and understand environmental conditions and the willingness to engage in pro-environmental actions. This empathy is an important aspect that drives environmental behaviors and commitments and sustainability behavior (Ienna et al., 2022; Wang et al., 2023).

Sustainability has become a central theme in higher education that contributes to the long-term success of this goal (Slocum et al., 2019; Scavarda et al., 2023). Universities play a key role in achieving the SDG goals integrated into the *tri dharma* of higher education: teaching, research, and community service. As centers of excellence, universities will assist the central and regional governments in preparing, implementing, monitoring, evaluating, and reporting the SDGs' action plan in Indonesia. The role of universities is manifested concretely through establishing SDG centers throughout Indonesia (Bappenas, 2023).

Education for Sustainable Development is now essential in empowering students at all educational levels to promote sustainable development in various contexts, equipping them with the skills and competencies needed to address the challenges of sustainability (Zdonek et al., 2017; García-Feijoo et al., 2020; Riess et al., 2022). ESD highlights the pivotal role of education in achieving the SDGs by demonstrating how education is interwoven with various goals, such as reducing poverty (SDG1), enhancing employment opportunities (SDG8), and promoting awareness of climate change impacts (SDG13) (UNESCO, 2018; Eliyawati et al., 2023). The ESD framework also aims to optimize the role of education in developing a more sustainable society and world by providing knowledge, values, attitudes, and skills related to sustainable development to encourage and develop a just and responsible way of life towards society, the environment, and the economy (Purnamasari & Hanifah, 2021). Furthermore, ESD provides students with essential knowledge, such as disaster management strategies, good practices, and preparedness planning, to support disaster prevention through informed mitigation efforts (Khorram-Manesh et al., 2016; Oktari et al., 2020; Nasution et al., 2020)

The escalating frequency and intensity of environmental disasters underscore the imperative for robust educational frameworks that cultivate competencies in sustainable development

and foster environmental empathy. Education for Sustainable Development (ESD) has emerged as a pivotal approach, aiming to equip individuals with the knowledge, skills, and values necessary to contribute to a sustainable future. Environmental awareness is a major topic of concern that seeks to turn countries, communities, and local actors towards more environmentally conscious actions, is reflected in students' attitudes and willingness to take concrete actions to protect the environment (Cernicova-Buca et al., 2023; Hanifha et al., 2023). Central to ESD is developing key competencies that enable individuals to critically reflect on their actions, considering their social, cultural, economic, and environmental impacts, both locally and globally. These competencies empower individuals to navigate complex situations sustainably and participate actively in sociopolitical processes that steer societies toward sustainable development (Cebrián et al., 2020).

Environmental empathy, defined as the capacity to understand and share the feelings of others concerning environmental issues, plays a crucial role in motivating pro-environmental behaviors and fostering a deeper connection to ecological systems. Integrating environmental empathy into educational strategies, particularly within the context of disaster mitigation, enhances students' emotional engagement and responsiveness to environmental challenges. Previous research indicates that understanding the relationship between ESD competencies and environmental empathy is critical to developing individuals capable of leading sustainability efforts in line with the goals of the 2030 Agenda for Sustainable Development (Kazakova et al., 2020; Pratama, 2020).

Many studies on Education for Sustainable Development (ESD) in Indonesia have focused on school-based initiatives such as the *Adiwiyata* program, which aims to cultivate students' environmental awareness (One Planet Network, 2015; Prasetiyo et al., 2020). However, these studies provide limited insights into whether students develop a comprehensive set of sustainability competencies (Rachman et al., 2024). A major research gap lies in the lack of thorough assessments, which most studies focus on evaluating students' environmental knowledge and behavioral changes rather than examining their acquisition of key ESD competencies such as systems thinking, critical thinking, and problem-solving (Rieckmann & Marco, 2018; Perdani et al., 2024). Furthermore, the relationship between ESD competencies and environmental empathy, particularly within disaster and environmental knowledge, remains largely unexplored (Leicht et al., 2018). While international studies indicate a strong link between sustainability education and increased empathy toward the environment (Rieckmann & Marco, 2018), there is still a lack of research investigating whether this relationship holds within Indonesia's unique cultural and environmental landscape (Kodir et al., 2022; Fatimah et al., 2025). Another key gap concerns the role of higher education institutions in fostering ESD competencies. Most research has concentrated on K-12 education (One Planet Network, 2015; Kodir et al., 2022), with relatively few studies examining how universities integrate ESD into their curricula and whether they effectively equip students to tackle sustainability challenges. Given Indonesia's geographical vulnerability to natural disasters as part of the *Ring of Fire* (Sugiyanto et al., 2024), enhancing disaster preparedness education is crucial by expanding students' knowledge and fostering socio-environmental empathy to inspire meaningful action. However, existing educational strategies may not yet sufficiently develop these essential competencies.

This study aims to address the identified gaps by assessing students' Education for Sustainable Development (ESD) and examine the correlation between ESD and students' environmental empathy in disaster and environmental knowledge at Universitas Syiah Kuala. Specifically, this study will develop an integrated educational framework that combines ESD competencies with environmental empathy, tailored to disaster and environmental education, and design and implement a participatory pedagogical approach to enhance students' empathetic responses and competencies related to disaster mitigation and environmental sustainability.

By addressing these areas, this study seeks to contribute to the advancement of educational strategies that not only provide essential knowledge and skills but foster the emotional and empathetic dispositions necessary for proactive engagement in sustainability and disaster mitigation efforts.

Therefore, this research contributes to advancing educational practices and fostering individuals who are empathetic toward the environment and capable of driving sustainable initiatives. It is also hoped that this study can provide recommendations for improving the curriculum and teaching methods to support SDG 2030 more effectively.

METHODS

This study used a correlational explanatory design, combining quantitative and qualitative approaches to determine the relationship between two variables (Creswell & Creswell, 2018): ESD competencies and environmental empathy. Quantitative correlation explores the numerical relationship between variables, while qualitative correlation tests the relationship based on descriptive (non-numerical) interview results to obtain in-depth information and verify and clarify existing data. The variables of this research were ESD competencies as the independent variable (X) and environmental empathy as the dependent variable (Y). The relationship model between these two variables is described in Figure 1.

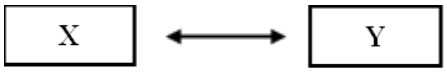

Figure 1. Research Design
Description:
X: ESD Competencies
Y: Environmental Empathy
⟷ : Relationship between X and Y

The population of the study was students at Syiah Kuala University (USK) class of 2023 who took the General Disaster and Environmental Education Course, totaling 2853 students. This study used 339 samples selected by random sampling from the 2853 population. The sample size was determined using a sample size calculator, with a confidence level of 95%. Additionally, to gain deeper insights, interviews were conducted with five students. Participants were selected based on their test scores, ensuring a representative sample for further exploration.

The survey was conducted in July-August 2024. The questionnaire was distributed online via Google form and through course instructors or shared in class WhatsApp group.

The research instruments consist of test instruments and non-test instruments. The test instrument for measuring ESD competency was developed based on UNESCO indicators. Furthermore, Variables, Competencies, scales, and indicators used in this research are shown in Table 1.

Table 1. Variables, Competencies and Scales, and Indicators Used in This Research

Variables	Competencies and Scales	Indicators
ESD competency	Systems thinking competencies	Recognition and understanding of relationships
		Analysis of complex systems
	Critical thinking competencies	Comprehension of systems across various domains and scales
		Sustainable decision-making capability in problem-solving contexts
		Analysis of norms, actions, and opinions
		Reflection on personal values and perspectives
		Ability to establish positions in sustainability discourse
Environmental empathy	The Environmental Attitude Scale	Environmental problems
		Conservation
	Pro-Environmental Behavior Scale	Energy Conservation
		Mobility and transportation
		Waste avoidance
		Recycling
		Consumerism

Expert validators assessed the instrument and systematically evaluated it according to predefined indicators. These indicators were selected to ensure a comprehensive and accurate evaluation of the instrument's effectiveness. The results of this evaluation are detailed and presented in Table 2, offering a clear overview of the validation process and its outcomes.

Table 2. Experts' Validation

Experts	Item Relevancy	Instrument Items	
		Systems Thinking Competency Instrument	Critical Thinking Competencies Instrument
Experts 1	Very Relevant item	1, 2, 3, 4, 5, 6,7, 8	1, 2, 3, 4, 5, 6
	Not Relevant item	-	-
Experts 2	Very Relevant item	1, 2, 3, 4, 5, 6,7, 8	1, 2, 3, 4, 5, 6
	Not Relevant item	-	-
Experts 3	Very Relevant item	1, 2, 3, 4, 5, 6,7, 8	1, 2, 3, 4, 5, 6
	Not Relevant item	-	-
Experts 4	Very Relevant item	1, 2, 3, 4, 5, 6,7, 8	1, 2, 3, 4, 5, 6
	Not Relevant item	-	-

Based on Table 2, all four expert validators unanimously agreed on the validity of the instrument items for this study. The researchers calculated the Aiken's validity index for each item to establish content validity further. The item validity index was analyzed by calculating the score set by each expert minus the lowest score in the category, then dividing by the number of experts, multiplying by the number of categories that the expert could choose, and dividing by 1. The results of Aiken's validity index analysis are presented in Table 3.

Table 3. Aiken's Item Validity Index Analysis

	Systems Thinking Competency Instrument		Critical Thinking Competencies Instrument	
No	V	Description	V	Description
1	0.92	Valid	1	Valid
2	0.70	Valid	0.98	Valid
3	1	Valid	0.98	Valid
4	0.83	Valid	1	Valid
5	0.97	Valid	0.89	Valid
6	0.83	Valid	0.94	Valid
7	0.64	Valid		
8	0.81	Valid		

The aggregate validation coefficient yielded a value of 0.89, indicating high overall content validity. Item analysis revealed that all questions demonstrated satisfactory validity, with coefficients ranging from moderate to high. From the original instrument, four systems thinking items were selected (one per indicator) based on superior validity coefficients, while three critical thinking items were chosen (one per indicator) using the same selection criteria. This selective approach ensured content validity and measurement efficiency, resulting in a final instrument comprising seven items: four assessing systems thinking competency and three assessing critical thinking competencies. The selection process maintained construct coverage while optimizing psychometric properties, ensuring each core indicator was represented by its most substantial performing item.

The non-test instrument was a questionnaire to measure environmental empathy. This instrument combined the Environmental Attitude Scale and the General Ecological Behavior Scale, which were adapted into Indonesian. The Environmental Attitude Scale (Weigel & Weigel, 1978) consisted of two aspects, comprising 16 items with five response options: Strongly Disagree, Disagree, Neutral, Agree, Strongly Agree. A higher score on this scale indicates a more positive attitude toward the environment. The internal consistency of the Environmental Attitude Scale was measured with Cronbach's alpha ($\alpha = 0.698$). The two aspects of the Environmental Attitude Scale are displayed in Table 4.

Table 4. Aspects of the Environmental Attitude Scale

No.	Aspect	Total of Question
1	Environmental problems	10
2	Conservation	6

The General Ecological Behavior Scale by Kaiser et al. (2007) consisted of six aspects, comprising 33 items with five response options: (1) Never, (2) Rarely, (3) Sometimes, (4) Often, (5) Always. The higher the Pro-Environmental Behavior Scale score corresponds to, the more positive the subject's behavior towards the environment. The internal consistency scale of Pro-Environmental Behavior was also measured with Cronbach's alpha ($\alpha = 0.801$). The aspects of the Pro-Environmental Behavior Scale are presented in Table 5.

Table 5. Aspects of the Pro-Environmental Behavior Scale

No.	Aspect	Total of Question
1	Energy Conservation	4
2	Mobility and transportation	3
3	Waste avoidance	6
4	Recycling	6
5	Consumerism	8
6	Vicarious behaviors toward conservation	6

Data analysis was carried out in several stages: collection, identification, analysis, and conclusion. Data was analyzed using Microsoft Excel 2019 and SPSS 23. The percentage of ESD competency is calculated by dividing the obtained score by the total score and then multiplying by 100. The respondents' calculated scores were then classified based on the system thinking ability critical thinking competencies category in Table 5.

Table 5. Systems and Critical Thinking Competency Criteria

Competency	Percentage	Criteria
Systems Thinking Competency Criteria (Nuraeni et al., 2020)	76-100	Excellent
	51-75	Good
	26-50	Adequate
	< 25	Inadequate
Critical Thinking Competency Criteria (Sobari et al., 2022)	86-100	Highly Critical
	76-85	Critical
	60-75	Moderately Critical
	55-59	Less Critical
	<55	Poorly Critical

Pearson's correlation test examined the correlation between ESD competencies and environmental empathy. Correlation analysis measures the strength and direction of the relationship between two quantitative variables. The correlation coefficient indicates the degree of association: values close to 1 or -1 suggest a strong relationship, while values near 0 indicate little to no correlation. A correlation coefficient below ±0.40 is considered low, between 0.40 and 0.60 is moderate, and above 0.60 is high (Obilor & Amadi, 2018). This analysis assessed the relationship bet-

ween the independent variable (ESD competencies) and the dependent variable (environmental empathy). Before conducting the Pearson's Product Moment analysis, the following assumption tests were performed:

Normality test: to determine whether the distribution of research data is normally distributed.

Linearity test: To determine whether the independent data variable is related to the dependent linear variable.

RESULTS AND DISCUSSION

The ESD competencies measured include systems thinking competencies and critical thinking competencies. According to UNESCO (2017), systems thinking competencies have four indicators: recognizing and understanding relationships, analyzing complex systems, thinking about how systems are embedded within different domains and scales, and making informed decisions about long-term solutions for uncertain problems. Critical thinking competencies, on the other hand, are assessed using three indicators: questioning norms, practices, and opinions, reflecting on one's values, perceptions, and actions; and taking a stance in sustainability discourse.

The survey results indicated that the average score for students' systems thinking competency was 73.67%, placing it within the "good" category. Figure 3 shows the comparison of percentages based on each system thinking competency indicator.

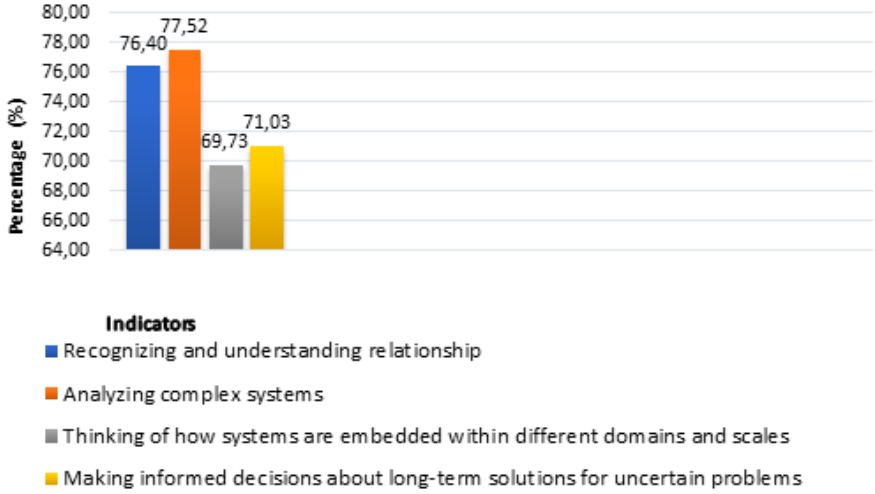

Figure 3. Achievement of Each System Thinking Competency Indicator

Systems thinking is the ability to see the whole picture of a complex problem by understanding the relationships between its parts. It involves an in-depth analysis of the patterns and interactions between the elements forming the system (Clark et al., 2017).

The results indicate that research participants understand nature as a complex system, contributing to the development of environmental empathy. However, they still view human interactions with nature as separate from the natural system (Restall & Conrad, 2015; Ekselsa et al., 2023). Among the measured indicators, "Analyzing complex systems" obtained the highest percentage score from the other indicators because systems thinking inherently promotes a holistic approach, encouraging individuals to view problems as interconnected wholes. This perspective enhances one's ability to analyze complex systems by recognizing patterns, relationships, and dynamics that might be overlooked when focusing on isolated components. Research indicates that systems thinking competencies are crucial for addressing the fluidity and complexity of environments (Skaržauskiene, 2010).

In addition, analyzing complex systems helps understand and navigate complex systems (Dittmer et al., 2023). This indicator helps individuals categorize problems based on their characteristics, leading to more effective analysis and decision-making. Studies have explored how complex systems' specifics affect the development of systems thinking skills (Mambrey et al., 2020; Seher Budak & Defne Ceyhan, 2024). In summary, the higher proficiency in analyzing complex systems within systems thinking competency arises from a combination of holistic perspectives, structured analytical frameworks, targeted educational practices, and the application of universal cognitive patterns (Grohs et al., 2018). These ele-

ments collectively foster a deeper understanding and capability to navigate and analyze complex systems. The indicator "Thinking about how systems are embedded in different domains and scales" obtained the lowest percentage score. This result aligns with Karaarslan Semiz and Teksöz (2020), noting that understanding the nature of the system cycle and adapting systems thinking to life remains challenging.

Figure 4. Achievement of Each Indicator of Critical Thinking Competence

The urgency of the 21st-century challenges underscores the importance of critical thinking competence, a primary objective of the educational process. Figure 4 shows that the average achievement of students' critical thinking competence is 71.64% (adequate category). According to Sobari et al. (2022), students' low critical thinking competence is caused by the learning processes that do not effectively cultivate critical thinking skills. These skills are also not innate and can be developed, practiced, and enhanced through learning (Ritdamaya & Suhandi, 2016).

To achieve high-quality and competency-based ESD, alternative methods are needed to actively engage students, motivate critical thinking, and promote holistic problem-solving that supports sustainable development (Yeung et al., 2017). Critical thinking is also the basis of continuing education (Sterling & Thomas, 2006), requiring a different learning approach from the traditional approach. In this case, Brookfield (2005) views critical thinking as individuals recognizing and examining their underlying assumptions before adopting a viewpoint that contrasts with their usual beliefs and behaviors. Figure 4 further shows varying percentage scores across the indicators of critical thinking competence: 68.79%, 65.31%, and 80.83%. Based on these data, the lowest percentage was recorded for "reflecting on one's values, perceptions and actions."

The analysis reveals a higher percentage of individuals demonstrating competency in "taking a position in sustainability discourse" compared to "questioning norms, actions, and opinions" and "reflecting on one's values, perceptions, and actions." This pattern can be attributed to several interrelated factors, primarily emphasizing action-oriented outcomes in educational environments. Educational institutions tend to prioritize competencies that yield observable actions and measurable decisions. The ability to take a position in sustainability discourse manifests through concrete outcomes such as advocacy initiatives, policy recommendations, and strategic planning, making it more amenable to assessment. This finding aligns with Redman and Wiek (2021) and Amprazis and Papadopoulou (2024), who emphasize that competencies enabling informed decision-making and responsible action are fundamental to sustainability education.

The second highest achievement was the ability to "question norms, actions, and opinions," constituting a foundational element of critical thinking. However, these skills are often developed at an early stage of education and may not be assessed at a more advanced level. In contrast, taking a stand in sustainability discourse is a more explicit application of critical thinking, which aligns with sustainability education's goals. UNESCO (2017) emphasizes that critical thinking involves questioning norms and reflecting on one's values, leading to active participation in sustainability discussions.

The predominance of position-taking ability in sustainability discourse reflects the convergence of multiple factors: educational emphasis, professional relevance, cultural values, and assessment methodologies that favor action-

oriented competencies. While questioning norms and reflecting on personal values remain integral to critical thinking, their introspective nature may contribute to their comparatively lower representation in competency assessments. This finding suggests the need for more balanced assessment approaches that equally value both action-oriented and reflective competencies in sustainability education.

ESD competencies play a crucial role in shaping students' environmental empathy, motivating them to take meaningful actions to address environmental degradation in alignment with sustainable development goals. ESD is not just a buzzword but also a call to action. This study investigated how students answer this call in the context of environmental issues. The results also showed that students' systems thinking competence, specifically in recognizing and understanding relationships, enhanced their awareness of climate change and its impact on coral reef degradation, which they identified as endangered marine treasures.

This study revealed how students view this crisis and their role in preserving it. An interesting finding from this study is that students with higher ESD competencies tend to have greater empathy for environmental degradation and are more proactive in finding solutions. "In-depth analysis of data interviews revealed that although students have a good understanding of the causes of coral reef degradation, for example, the gap between understanding and real action remains." This study indicates that ESD has excellent potential in equipping students with the knowledge, skills, and values needed to become environmentally responsible citizens (Sari, 2023). Most students understand climate change is a major factor causing coral reef damage. For example, Student A states, *"Climate change is the main cause of coral damage because the warmer sea temperatures are causing the coral to bleach*."

On the indicator of analyzing complex systems, the results of the qualitative analysis obtained are valuable for understanding how students view environmental issues, especially waste management, in the context of ESD and SDGs. The questions presented highlight that Indonesia continues to face significant challenges in waste management. This study explored students' perspectives on this issue and their perceived role in contributing to potential solutions. Student A and Student C's example of waste management was "t*he government needs to establish stricter policies regarding the use of disposable bags*."

On the other hand, regarding environmental awareness and individual responsibility, Student D stated, *"he will start reducing the use of single-use plastics and invite my friends to do so*." Those statements showed that students with a better understanding of the product life cycle were more likely to reduce plastic use. This finding supports the core concept of ESD, which is holistic systems thinking (UNESCO, 2018) and an understanding of the relationship between human activities and the environment. It also aligns with SDG 12's goal to increase sustainable production and consumption (Bengtsson et al., 2018; Capah et al., 2023). ESD Education should emphasize understanding the product life cycle to encourage behavioral change (Scalabrino et al., 2022).

Furthermore, the indicator assessing students' ability to think about systems across different areas and scales examines their understanding of the interconnections between economic, social, and environmental aspects and their ability to design holistic solutions and take action to drive change. Student C stated, "E*conomic, social, and environmental cannot be separated. These three aspects are closely related*." Student B argued that "*Industry must also be given space to utilize forests, but forests still need to be replanted" in the conflict between agricultural and industrial expansion and forest conservation.*" Student A offered an alternative solution, suggesting that "*Industry players must also review the studies about other alternatives for paper making, for example, using non-tree materials to avoid always sacrificing nature. Such Ideas must be considered and developed so that forests, economy, and society are safe*".

By analyzing students' system thinking abilities, policymakers and educators can better understand how ESD education equips students with the necessary tools to address complex environmental problems (Rieckmann, 2018). The findings of this study can make an important contribution to developing a more effective ESD curriculum.

The last indicator of system thinking competencies—making decisions in sustainable discourse as a solution to an uncertain phenomenon, requires an in-depth analysis of students' ability to think systematically, analyze complex situations, and formulate sustainable solutions. The aim is to assess how well students can apply ESD competencies in real contexts, especially in dealing with environmental problems such as plastic pollution.

A study showed that an ESD approach oriented towards values and sustainable actions can effectively increase students' environmental sen-

sitivity. These findings indicate the great potential of ESD to integrate a global change perspective into education. Based on the interview excerpt, Student E stated that "*plastic pollution in water contaminates the environment, and fish can ingest plastic."* Similarly, Student C commented, "*Plastic pollution damages the ecosystem and disrupts people's livelihoods*." These responses illustrate that they can connect decision-making abilities with SDGs.

What has been found from this study aligns with Sachs (2012), who argued that sound decision-making is key to achieving the Sustainable Development Goals (SDGs). When individuals, especially the younger generation, consider social, economic, and environmental factors, they directly contribute to achieving the SDGs. In addition, Yamane and Kaneko (2021), who conducted two online surveys in Japan with 12,098 adults and 668 students, analyzing sustainable lifestyle choices and career preferences related to company contributions to the SDGs, found a positive tendency of the younger generation toward sustainable development goals.

Regarding critical thinking competence in ESD, the responses indicate that the students have demonstrated some critical thinking skills, but some areas need improvement. The questions addressed opinions on why individuals remain reluctant to abandon single-use plastic bags despite numerous campaigns highlighting their negative environmental impacts. The participants identified several factors contributing to this reluctance, such as habits, availability, and price. They proposed potential solutions, such as providing subsidies for environmentally friendly products, more intensive education, and stricter regulations.

However, several areas can be improved, such as the depth of analysis. Some responses remained general rather than specific. For example, when discussing education, students must explain in more detail what type of education is effective and how to implement it. Similarly, when proposing solutions, students should critically evaluate the solutions. For example, while providing subsidies for environmentally friendly products may be effective in the short term, how would these subsidies impact the plastic industry in the long run? The interview results on this indicator align with the test instrument outcomes, which categorized students' critical thinking abilities as moderately critical.

According to Bendell et al. (2017), the ability to face risks and ambiguity and develop critical thinking are pillars of transformative learning. However, student motivation often decreases after completing the program. This study supports an active learning approach to achieving the SDGs, in line with academics' calls to shift from traditional teaching to more innovative approaches (Correa & Larrinaga, 2015; Scheyvens et al., 2016; Lozano et al., 2017; Molderez & Fonseca, 2018).

A creative learning environment can equip students with the necessary soft skills to understand the complexity of interactions between business, society, and the environment, fostering long-term commitment (Slahova et al., 2007). Furthermore, the indicator assessing the ability to reflect on one's values, views, and actions aimed to evaluate students' ability to reflect on their values, views, and actions related to energy efficiency based on the interview transcripts provided. This competency is important in the context of ESD because it shows the extent to which individuals are aware of their role in achieving SDGs (Taimur & Sattar, 2020), especially regarding energy efficiency.

For example, Student B stated, "A*t home, during the day, I turn off the lights and reduce television usage. However, I use a fan for 24 hours because of the hot weather. Saving energy is difficult to implement fully, but I tried with small actions like turning off the lights during the day".* The transcripts indicate that respondents have shown some level of self-reflection, but some areas need improving. Specifically, their reflections tend to be superficial. Respondents need to dig deeper into the reasons behind their actions or decisions. In addition, respondents also need to connect their actions with the values they adhere to, such as concern for the environment or social responsibility.

The last indicator of critical thinking competence in ESD is the ability to take a position in the sustainability discourse. This analysis aimed to evaluate the extent to which students can take a clear position or attitude regarding sustainability issues, especially in the context of recycling programs. This ability shows students' level of understanding and concern towards environmental issues and their willingness to be involved in environmental conservation efforts.

Based on the interviews, it is evident that respondents have taken a clear position regarding the importance of recycling programs. Student C remarked, "*Recycling programs are crucial. Indonesia could follow Singapore's example, where waste is converted into electrical energy. I hope that Indonesia will develop more solutions to overcome this waste in the future because plastic cannot be separated from society. The government needs to create regulations to address this issue*". Several key points can be drawn from this statement. First, the respondent clearly emphasized the importance of recycling programs in Indonesia, demonstrating an awareness of their positive environmental impact.

Second, by comparing Indonesia's situation with Singapore's, the respondent understood that Indonesia could learn from other countries and implement improvements. Lastly, the respondent expressed expectations for the government to take a more active role in waste management and encourage public participation in recycling programs, indicating trust in the government's capacity to address environmental challenges. In conclusion, students have demonstrated a good understanding of the importance of recycling programs. However, to enhance their ability to engage in broader sustainability discourse, initiatives such as community-based projects related to sustainability issues should be facilitated (Purnamasari & Nurawaliyah, 2023).

Table 7. Kolmogorov-Smirnov Normality Test

		Unstandardized Residual
N		339
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	.34508457
Most Extreme Differences	Absolute	.042
	Positive	.042
	Negative	-.029
Test Statistic		.042
Asymp. Sig. (2-tailed)		.200[c,d]

Based on the results of the normality test in Table 7, the Kolmogorov-Smirnov test indicates that the data were normally distributed (p=0.200).

Table 8. Linearity Test

			Sum of Squares	df	Mean Square	F	Sig.
Environmental empathy * ESD competency	Between Groups	(Combined)	6.490	29	.224	1.817	.008
		Linearity	4.292	1	4.292	34.850	.000
		Deviation from Linearity	2.198	28	.079	.638	.924
	Within Groups		38.052	309	.123		
	Total		44.542	338			

The results of the linearity test in Table 8 show that the Sig. Deviation from the linearity value is 0.924 > 0.05, so it can be concluded that there is a linear relationship between ESD competencies and environmental empathy.

Based on the results of the data prerequisite test conducted through the normality test (Table 7) of the distribution of both variables, the ESD competency variable and the environmental empathy variable were declared normal. Likewise, through the linearity test of the relationship (Table 8), the relationship between the two was declared linear. This shows that both variables meet the requirements for analysis using the parametric correlation technique.

Table 9. Pearson's Correlation Test

		ESD Competency	Environmental Empathy
ESD Competency	Pearson Correlation	1	.310**
	Sig. (2-tailed)		.000
	N	339	339
Environmental Empathy	Pearson Correlation	.310**	1
	Sig. (2-tailed)	.000	
	N	339	339

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation test results indicate that Pearson's correlation coefficient is statistically significant (p=0.01, r=0.310, N=339), indicating a significant relationship between ESD competencies and environmental empathy. However, the correlation is categorized as low, given that the correlation coefficient (r) is below 0.40 (Obilor & Amadi, 2018). Thus, it can be concluded that ESD competencies positively correlate to environmental empathy, but their magnitude is low.

The analysis reveals that students' systems thinking competence in the Environmental Disaster Knowledge Course are categorized as "good," while their critical thinking competence is classified as "adequate." Despite the positive correlation between ESD competencies and environmental empathy (p = 0.000), the weak correlation suggests that various complex, interrelated factors may influence this relationship. Internal factors include environmental knowledge, attitudes, environmental awareness, locus of control, responsibility, and priority. External factors include economic, social, cultural, and institutional factors. Demographic factors include gender and years of education (Kollmuss & Agyeman, 2002). Among the internal factors, attitude plays a particularly significant role.

In addition, cognitive factors and experiences also influence environmental empathy. Individuals who experience deeper emotional involvement tend to show greater empathy toward living beings and the environment. Wibowo et al. (2024) state that critical thinking skills positively impact concern for living beings and the environment. Similarly, early exposure to nature can foster a strong sense of environmental care. Therefore, the weak correlation between ESD competencies and environmental empathy among students in the Disaster and Environmental Studies course at USK may be linked to the limited capacity of individuals to integrate knowledge and experience into their values. Understanding how individual values shape attitudes and behaviors toward the environment is crucial in promoting behavioral change toward sustainability. By understanding the values held by a particular community group, we can design more effective messages and educational programs to change behavior.

External factors, including the social environment and formal education, also play a critical role in shaping environmental empathy. Family, friends, and social norms influence individuals' attitudes and behaviors toward the environment. Peer pressure and expectations from social groups can drive pro-environmental actions. Additionally, formal education is essential for cultivating environmental empathy, as it provides individuals with the knowledge, skills, and values necessary to understand environmental complexities and develop a sense of responsibility toward nature. Formal education holds considerable potential for fostering environmental empathy. Education can inspire the younger generation to become agents of change in environmental conservation by imparting the appropriate knowledge, skills, and values.

While the Disaster and Environment course at USK has been implemented, the low correlation between systems thinking and critical thinking competencies suggests that although students have received environmental education, their behaviors do not yet reflect environmentally friendly practices. This circumstance could be due to the failure of educational approaches to translate knowledge and attitudes into tangible, pro-environmental behaviors. As a result, the material does not foster moral understanding or awareness, and environmental behaviors are not internalized in daily life.

Similarly, classroom learning often fails to emphasize the importance of responsibility. According to Septian et al. (2016), responsibility is the highest level of attitude, where individuals make decisions independently after understanding the associated risks. Identifying factors contributing to the weak correlation between ESD competencies and environmental empathy is essential for designing more effective educational programs and interventions. A more holistic and integrated approach to enhancing environmental awareness through systems thinking and critical thinking skills can be developed by addressing these factors.

Empathetic behavior is influenced by several factors: socialization, cognitive development, mood, situation, and communication. Empathy for the environment can also be caused by psychological factors, which in turn promote pro-environmental behavior. Ienna et al. (2022) found that empathy positively correlates with individual pro-environmental behavior. Where the higher the empathy, the higher the pro-environmental behavior. Berenguer (2007) also supports this, demonstrating that when individuals develop greater empathy, they will be more willing to behave positively towards their environment.

These findings highlight the complex interplay between ESD competencies and environmental empathy. While strengthening systems thinking and critical thinking is crucial for sustainability education, fostering environmental empathy may require additional interventions

beyond traditional competency-based learning. To enhance environmental empathy, educators should consider integrating experiential learning, such as real-world environmental problem-solving and disaster response activities, encouraging reflective and emotional engagement in classroom discussions to help students internalize sustainability issues, and examining individual differences in student backgrounds to tailor ESD approaches that resonate with diverse perspectives.

This study did not include a comparison of correlation data between ESD competencies and student empathy before and after taking the course. Such a comparison would provide more precise insights into the correlation between these variables. This limitation suggests a potential direction for future research, which could focus on pre- and post-course analyses to assess ESD's impact on environmental empathy comprehensively. Future research should explore additional mediating factors, such as personal motivation, emotional intelligence, and cultural context, to better understand the dynamics between ESD competencies and environmental empathy.

CONCLUSION

The assessment results show that the average score for students' systems thinking competency was 73.67%, placing it within the "good" category, and students' critical thinking competence is 71.64% (adequate category). Furthermore, the results of the correlation between ESD competencies and environmental empathy among students enrolled in the USK's Disaster and Environmental Studies course were found. The analysis results with Pearson r = 0.310 show that ESD competencies positively correlate with environmental empathy, with a low correlation magnitude. This suggests that although ESD competencies enhance environmental empathy, other factors may also be at play. These findings emphasize that ESD competencies contribute to environmental empathy, but their impact is relatively small if not combined with learning strategies that foster emotional engagement and direct experience. Therefore, a more holistic ESD approach that combines direct experience (*experiential learning*), action-based, and oriented to real experiences is needed to optimize the formation of environmental empathy and support the achievement of SDGs 2030. A qualitative analysis of interview responses indicates that students have the potential to become agents of change in realizing sustainable development. Data collection through essay questions, environmental empathy questionnaires, and interviews provides a more comprehensive picture of the extent to which students understand and feel concern for environmental issues. These findings provide important insights for developing more effective ESD programs at the university level. Programs focusing on improving ESD competencies can strengthen students' environmental empathy, contributing to achieving the Sustainable Development Goals (SDGs) by 2030. With this understanding, universities and stakeholders can design more integrated curricula and increase student engagement in sustainability actions. Further research can explore other factors influencing environmental empathy, such as personal experiences, peer influence, or social media influence. In addition, research can also identify the most effective educational methods or approaches in improving students' ESD competencies and environmental empathy.

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REFERENCES

Agbedahin, A. V. (2019). Sustainable Development, Education for Sustainable Development, and the 2030 Agenda for Sustainable Development: Emergence, Efficacy, Eminence, and Future. *Sustainable Development*, *27*(4), 669–680.

Ahmad, N., Toro-Troconis, M., Ibahrine, M., Armour, R., Tait, V., Reedy, K., Malevicius, R., Dale, V., Tasler, N., & Inzolia, Y. (2023). CoDesignS Education for Sustainable Development: A Framework for Embedding Education for Sustainable Development in Curriculum Design. *Sustainability*, *15*(23), 16460.

Amprazis, A., & Papadopoulou, P. (2024). Key Competencies in Education for Sustainable Development: A Valuable Framework for Enhancing Plant Awareness. *Plants People Planet*.

Bappenas. (2023). *SDGs Center*. [Online]. Accessed Via Https://Sdgs.Bappenas.Go.Id/Jejaring/Sdgs-Center-Pt/ On May 22, 2024.

Bendell, J., Sutherland, N., & Little, R. (2017). Beyond unsustainable leadership: Beyond Unsustainable Leadership: Critical Social Theory for Sustainable Leadership. *Sustainability Accounting, Management and Policy Journal*, *8*(4), 418–444.

Bengtsson, M., Alfredsson, E., Cohen, M., Lorek, S., & Schroeder, P. (2018). Transforming Systems

of Consumption and Production for Achieving the Sustainable Development Goals: Moving Beyond Efficiency. *Sustainability Science*, *13*(6), 1533–1547.

Berenguer, J. (2007). The Effect of Empathy in Proenvironmental Attitudes and Behaviors. *Environment and Behavior*, *39*(2), 269–283.

Brookfield, S. D. (2005). *The Power of Critical Theory for Adult Learning and Teaching*. Maidenhead: Open University Press.

Capah, B. M., Rachim, H. A., & Raharjo, S. T. (2023). Implementasi SDG's-12 Melalui Pengembangan Komunitas dalam Program CSR. *Share: Social Work Journal*, *13*(1), 150-161.

Carlsen, L., & Bruggemann, R. (2022). The 17 United Nations' Sustainable Development Goals: A Status by 2020. *International Journal of Sustainable Development and World Ecology*, *29*(3), 219–229.

Cebrián, G., Junyent, M., & Mulà, I. (2020). Competencies in Education for Sustainable Development: Emerging Teaching and Research Developments. *Sustainability*, *12*(2), 579.

Cernicova-Buca, M., Dragomir, G. M., Gherheş, V., & Palea, A. (2023). Students' Awareness Regarding Environment Protection in Campus Life: Evidence from Romania. *Sustainability (Switzerland)*, *15*(23), 16444.

Clark, S., Petersen, J. E., Frantz, C. M., Roose, D., Ginn, J., & Daneri, D. R. (2017). Teaching systems thinking to 4th and 5th graders using Environmental Dashboard display technology. *PLoS ONE*, *12*(4), 1–11.

Correa, C., & Larrinaga, C. (2015). Engagement Research in Social and Environmental Accounting. *Sustainability Accounting, Management and Policy Journal*, *6*(1), 5–28.

Creswell, J. W., & Creswell, D. J. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches.* Sage Publications.

Dittmer, S., Roberts, M., Gilbey, J., Biguri, A., Selby, I., Breger, A., Thorpe, M., Weir-McCall, J. R., Gkrania-Klotsas, E., Korhonen, A., Jefferson, E., Langs, G., Yang, G., Prosch, H., Stanczuk, J., Tang, J., Babar, J., Escudero Sánchez, L., Teare, P., … Schönlieb, C.-B. (2023). Navigating the Development Challenges in Creating Complex Data Systems. *Nature Machine Intelligence*, *5*(7), 681–686.

Ekselsa, R. A., Purwianingsih, W., Anggraeni, S., & Wicaksono, A. G. C. (2023). Developing System Thinking Skills Through Project-Based Learning Loaded With Education for Sustainable Development. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *9*(1), 62–73.

Eliyawati, Widodo, A., Kaniawati, I., & Fujii, H. (2023). The Development and Validation of an Instrument for Assessing Science Teacher Competency to Teach ESD. *Sustainability (Switzerland)*, *15*(4). 3276.

Fatimah, Y. A., John, M., & Hasibuan, Z. A. (2025). Sustainability Education Development in Indonesia. In *The Routledge Handbook of Global Sustainability Education and Thinking for the 21st Century* (pp. 900–917). London: Routledge India.

Fleaca, B., Fleaca, E., & Maiduc, S. (2023). Framing Teaching for Sustainability in the Case of Business Engineering Education: Process-Centric Models and Good Practices. *Sustainability (Switzerland)*, *15*(3). 2035.

García-Feijoo, M., Eizaguirre, A., & Rica-Aspiunza, A. (2020). Systematic Review of Sustainable-Development-Goal Deployment in Business Schools. *Sustainability*, *12*(1), 440.

Giangrande, N., White, R. M., East, M., Jackson, R., Clarke, T., Saloff Coste, M., & Penha-Lopes, G. (2019). A Competency Framework to Assess and Activate Education for Sustainable Development: Addressing the UN Sustainable Development Goals 4.7 Challenge. *Sustainability*, *11*(10), 2832.

Goldstein, A. P., & Michaels, G. Y. (2021). *Empathy: Development, Training, and Consequences*. London: Routledge.

Grohs, J. R., Kirk, G. R., Soledad, M. M., & Knight, D. B. (2018). Assessing Systems Thinking: A Tool to Measure Complex Reasoning Through Ill-Structured Problems. *Thinking Skills and Creativity*, *28*, 110–130.

Halim, A. (2022). Signifikansi dan Implementasi Berpikir Kritis dalam Proyeksi Dunia Pendidikan Abad 21 pada Tingkat Sekolah Dasar. *Jurnal Indonesia Sosial Teknologi*, *3*(3), 404–418.

Hanifha, S., Erna, M., Noer, A. M., & Talib, C. A. (2023). Socioscientific Issue-Based Undergraduate Student Worksheets on Scientific Literacy and Environmental Awareness. *Jurnal Pendidikan IPA Indonesia*, *12*(4), 504–513.

Ienna, M., Rofe, A., Gendi, M., Douglas, H. E., Kelly, M., Hayward, M. W., Callen, A., Klop-Toker, K., Scanlon, R. J., Howell, L. G., & Griffin, A. S. (2022). The Relative Role of Knowledge and Empathy in Predicting Pro-Environmental Attitudes and Behavior. *Sustainability (Switzerland)*, *14*(8), 4622.

Kaiser, F. G., Oerke, B., & Bogner, F. X. (2007). Behavior-Based Environmental Attitude: Development of an Instrument for Adolescents. *Journal of Environmental Psychology*, *27*(3), 242–251.

Karaarslan Semiz, G., & Teksöz, G. (2020). Developing the Systems Thinking Skills of Pre-Service Science Teachers Through an Outdoor ESD Course. *Journal of Adventure Education and Outdoor Learning*, *20*(4), 337–356.

Kazakova, O. M., Malinovskaia, T. N., Fedulov, B. A., Romanova, E. V., Zavgorodnii, E. G., & Matveychuk, N. S. (2020). Ecological Awareness of University Students About UN Sustainable Development Goals At Global, National and Regional Levels. *Ukrainian Journal of Ecology*, *10*(1), 215–219.

Khorram-Manesh, A., Lupesco, O., Friedl, T., Arnim, G., Kaptan, K., Djalali, A. R., Foletti, M., Ingrasia, P. L., Ashkenazi, M., Arculeo, C.,

Fischer, P., Hreckovski, B., Komadina, R., Voigt, S., Carlström, E., & James, J. (2016). Education in Disaster Management: What Do We Offer and What Do We Need? Proposing a New Global Program. *Disaster Medicine and Public Health Preparedness*, *10*(6), 854–873.

Khoshnava, S. M., Rostami, R., Zin, R. M., Štreimikiene, D., Yousefpour, A., Strielkowski, W., & Mardani, A. (2019). Aligning the Criteria of Green Economy (GE) and Sustainable Development Goals (SDGs) to Implement Sustainable Development. *Sustainability (Switzerland)*, *11*(17). 4615.

Kioupi, V., & Voulvoulis, N. (2019). Education for Sustainable Development: A Systemic Framework for Connecting the SDGs to Educational Outcomes. *Sustainability (Switzerland)*, *11*(21). 6104.

Kodir, A., Syaifulloh, M., Monassa, I. I., Sumarmi, S., & Zubaidah, S. (2022). Environmental Education at Adiwiyata Schools and the Conservation of the Brantas Watershed in Indonesia. *KnE Social Sciences*, 301-306.

Kollmuss, A., & Agyeman, J. (2002). Mind The Gap: Why Do People Act Environmentally and What Are The Barriers to Pro-Environmental Behavior? *Environmental Education Research*, *8*(3), 239–260.

Kusumoto, Y. (2018). Enhancing Critical Thinking Through Active Learning. *Language Learning in Higher Education*, *8*(1), 45–63.

Ladan, M. T. (2018). Achieving Sustainable Development Goals Through Effective Domestic Laws and Policies on Environment and Climate Change. *Environmental Policy and Law*, *48*(1), 42–63.

Leicht, A., Heiss, J., & Byun, W. J. (2018). *Issues and Trends in Education for Sustainable Development* (Vol. 5). Paris: UNESCO Publishing.

Lozano, R., Barreiro-Gen, M., Pietikäinen, J., Gago-Cortes, C., Favi, C., Jimenez Munguia, M. T., Monus, F., Simao, J., Benayas, J., & Desha, C. (2022). Adopting Sustainability Competence-Based Education in Academic Disciplines: Insights from 13 Higher Education Institutions. *Sustainable Development*, *30*(4), 620–635.

Lozano, R., Merrill, M. Y., Sammalisto, K., Ceulemans, K., & Lozano, F. J. (2017). Connecting Competences and Pedagogical Approaches for Sustainable Development in Higher Education: A Literature Review and Framework Proposal. *Sustainability*, *9*(10), 1889.

Mensah, J. (2019). Sustainable Development: Meaning, History, Principles, Pillars, and Implications for Human Action: Literature Review. *Cogent Social Sciences*, *5*(1), 1653531.

Molderez, I., & Ceulemans, K. (2018). The Power of Art to Foster Systems Thinking, One of the Key Competencies of Education for Sustainable Development. *Journal of Cleaner Production*, *186*, 758–770.

Molderez, I., & Fonseca, E. (2018). The Efficacy of Real-World Experiences and Service Learning for Fostering Competences for Sustainable Development in Higher Rducation. *Journal of Cleaner Production*, *172*, 4397–4410.

Nasution, B. I., Kurniawan, R., Siagian, T. H., & Fudholi, A. (2020). Revisiting Social Vulnerability Analysis in Indonesia: An Optimized Spatial Fuzzy Clustering Approach. *International Journal of Disaster Risk Reduction*, *51*, 101801.

Novidsa, I., Purwianingsih, W., & Riandi, R. (2020). Exploring Knowledge of Prospective Biology Teacher About Education for Sustainable Development. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *6*(2), 317–326.

Obilor, E. I., & Amadi, E. C. (2018). Test for Significance of Pearson's Correlation Coefficient. *International Journal of Innovative Mathematics, Statistics & Energy Policies*, *6*(1), 11–23.

Oktari, R. S., Munadi, K., Idroes, R., & Sofyan, H. (2020). Knowledge Management Practices in Disaster Management: Systematic Review. In *International Journal of Disaster Risk Reduction*, 51, 101881.

One Planet Network. (2015). *Adiwiyata School Program in Indonesia*. [Online]. Accessed Via https://www.oneplanetnetwork.org/knowledge-centre/projects/adiwiyata-school-program-indonesia. On May 27, 2024.

Perdani, A. S., Sumardani, N. I., & Yuana, A. (2024). Key Educational Competencies for Sustainable Development in The Cultural Life of The Baduy Community. *Equator Science Journal*, *2*(2), 43–56.

Podgórska, M., & Zdonek, I. (2024). Interdisciplinary Collaboration in Higher Education Towards Sustainable Development. *Sustainable Development*, *32*(3), 2085–2103.

Prasetiyo, W. H., Ishak, N. A., Basit, A., Dewantara, J. A., Hidayat, O. T., Casmana, A. R., & Muhibbin, A. (2020). Caring for the Environment in an Inclusive School: The Adiwiyata Green School Program in Indonesia. *Issues in Educational Research*, *30*(3), 1040-1057.

Pratama, Y. P. (2020). Konsensus Kemitraan Global Pbb (MDGs & SDGs), Hipotesis Environmental Kuznet Curve (EKC), dan Degradasi Kualitas Udara di Indonesia Periode 1980-2018. *Diponegoro Journal of Economics*, *9*(4).

Purnamasari, S., & Hanifah, A. N. (2021). Education for Sustainable Development (ESD) dalam Pembelajaran IPA. *Jurnal Kajian Pendidikan IPA*, *1*(2), 69–75.

Purnamasari, S., & Nurawaliyah, S. (2023). Studi Literatur: Penilaian Kompetensi Keberlanjutan dan Hasil Belajar Education for Sustainable Development (ESD). *Jurnal Pendidikan UNIGA*, *17*(1), 686–698.

Rahman, A., Heryanti, L. M., & Ekanara, B. (2019). Pengembangan Modul Berbasis Education for Sustainable Development pada Konsep Ekologi Untuk Siswa Kelas X SMA. *Jurnal Eksakta Pendidikan (JEP)*, *3*(1), 1–8.

Redman, A., & Wiek, A. (2021). Competencies for

Advancing Transformations Towards Sustainability. *Frontiers in Education*, *6*, 785163.

Restall, B., & Conrad, E. (2015). A Literature Review of Connectedness to Nature and Its Potential for Environmental Management. *Journal of Environmental Management*, *159*, 264-278.

Rieckmann, M. (2018). Learning to Transform the World: Key Competencies in Education for Sustainable Development. *Issues and Trends in Education for Sustainable Development*, *39*(1), 39–59.

Rieckmann, & Marco. (2018). *Issues and Trends in Education for Sustainable Development*. Paris: Unesco Publishing.

Riess, W., Martin, M., Mischo, C., Kotthoff, H.-G., & Waltner, E.-M. (2022). How Can Education for Sustainable Development (ESD) Be Effectively Implemented in Teaching and Learning? An Analysis of Educational Science Recommendations of Methods and Procedures to Promote ESD Goals. *Sustainability*, *14*(7), 3708.

Ritdamaya, D., & Suhandi, A. (2016). Konstruksi Instrumen Tes Keterampilan Berpikir Kritis Terkait Materi Suhu dan Kalor, *J urnal Penelitian & Pengembangan Pendidikan Fisika, 2(2), 87-96.*

Sachs, J. D. (2012). From Millennium Development Goals to Sustainable Development Goals. *The Lancet*, *379*(9832), 2206–2211.

Sari, W. D. (2023). Education Sustainability Development (ESD) Teori pada Manajemen Pendidikan Islam di Era Digital. *Edukasi Islami: Jurnal Pendidikan Islam*, *12*(001).

Scalabrino, C., Navarrete Salvador, A., & Oliva Martínez, J. M. (2022). A Theoretical Framework to Address Education for Sustainability for an Earlier Transition to a Just, Low Carbon and Circular Economy. *Environmental Education Research*, *28*(5), 735–766.

Scavarda, A., Daú, G., Scavarda, L. F., Chhetri, P., & Jaska, P. (2023). A Conceptual Framework for the Corporate Sustainability Higher Education in Latin America. *International Journal Of Sustainability In Higher Education*, *24*(2), 481–501.

Scheyvens, R., Banks, G., & Hughes, E. (2016). The Private Sector and the SDGs: The Need to Move Beyond 'Business as Usual.' *Sustainable Development*, *24*(6), 371–382.

Schuler, S., Fanta, D., Rosenkraenzer, F., & Riess, W. (2018). Systems Thinking Within the Scope of Education for Sustainable Development (ESD)–A Heuristic Competence Model as a Basis for (Science) Teacher Education. *Journal of Geography in Higher Education*, *42*(2), 192–204.

Seher Budak, U., & Defne Ceyhan, G. (2024). Research Trends on Systems Thinking Approach in Science Education. *International Journal of Science Education*, *46*(5), 485–502.

Septian, Y., Ruhimat, M., & Somantri, L. (2016). Perilaku ramah lingkungan peserta didik SMA di kota Bandung. *Jurnal Pendidikan Geografi, 16(2),* 71-81.

Shulla, K., Filho, W. L., Lardjane, S., Sommer, J. H., & Borgemeister, C. (2020). Sustainable Development Education in the Context of the 2030 Agenda for Sustainable Development. *International Journal of Sustainable Development and World Ecology*, *27*(5), 458–468.

Shutaleva, A. (2023). Ecological Culture and Critical Thinking: Building of A Sustainable Future. *Sustainability*, *15*(18), 13492.

Skaržauskiene, A. (2010). Managing Complexity: Systems Thinking as a Catalyst of the Organization Performance. *Measuring Business Excellence*, *14*(4), 49–64.

Slahova, A., Savvina, J., Cacka, M., & Volonte, I. (2007). Creative Activity in Conception of Sustainable Development Education. *International Journal of Sustainability in Higher Education*, *8*(2), 142–154.

Slocum, S. L., Dimitrov, D. Y., & Webb, K. (2019). The Impact of Neoliberalism on Higher Education Tourism Programs: Meeting the 2030 Sustainable Development Goals With the Next Generation. *Tourism Management Perspectives*, *30*, 33–42.

Sobari, E. F. D., Hernani, H., & Ramalis, T. R. (2022). Critical Thinking Skills and Sustainability Conciousness of Students for the Implementation Education for Sustainable Development. *Journal of Science Education Research*, *6*(2), 75–80.

Stavroulia, K. E., & Lanitis, A. (2019). Enhancing Reflection and Empathy Skills Via Using a Virtual Reality Based Learning Framework. *International Journal of Emerging Technologies in Learning*, *14*(7), 18–36.

Sterling, S., & Thomas, I. (2006). Education for Sustainability: The Role of Capabilities in Guiding University Curricula. *International Journal of Innovation and Sustainable Development*, *1*(4), 349–370.

Sugiyanto, S., Muryani, C., & Ni'matussyahara, D. (2024). Strengthening Student Empathy in GeoCapabilities: Digital Learning Innovations and Pedagogical Strategies for Disaster Mitigation. Contemporary Educational Technology, 16(3), ep521.

Supriatno, B., Kusumawaty, D., Tallei, T. E., Emran, T. B., & Suwandi, T. (2023). Introducing CAPAB (L) E: A Learning Model to Promote Prospective Biology Teacher's Entrepreneurship Skills. *Jurnal Pendidikan IPA Indonesia*, *12*(2), 265-275.

Taimur, S., & Sattar, H. (2020). Education for Sustainable Development and Critical Thinking Competency. *Quality Education*, 238-248.

Tamsma, N., & Costongs, C. (2018). Promoting Health and Well-Being in the Context of the United Nations Sustainable Development Agenda. In *Scandinavian Journal of Public Health, 46*(1), 44-48.

United Nations Educational Scientific and Cultural Organization [UNESCO]. (2017). *Education for Sustainable Development Goals: Learning Objec-*

tives. [Online]. Accessed via https://www.Unsdglearn.Org/Unesco-Cross-Cutting-And-Specialized-Sdg-Competencies/ on Juny 12, 2024.

United Nations Educational Scientific And Cultural Organization [UNESCO]. (2018). *Issues And Trends In Education For Sustainable Development.* [Online]. Accessed via. https://unesdoc.unesco.org/ark:/48223/pf0000261954, on Juny 12, 2024

Velempini, K. (2025). Assessing the Role of Environmental Education Practices Towards the Attainment of the 2030 Sustainable Development Goals. *Sustainability*, *17*(5), 2043.

Wang, L., Sheng, G., She, S., & Xu, J. (2023). Impact of Empathy With Nature on Pro□Environmental Behaviour. *International Journal of Consumer Studies*, *47*(2), 652–668.

Weigel, R., & Weigel, J. (1978). Environmental Concern: The Development of a Measure. *Environment and Behavior*, *10*(1), 3–15.

Wibowo, A. M., Utaya, S., Wahjoedi, W., Zubaidah, S., Amin, S., & Prasad, R. R. (2024). Critical Thinking and Collaboration Skills on Environmental Awareness in Project-Based Science Learning. *Jurnal Pendidikan IPA Indonesia*, *13*(1).

Yamane, T., & Kaneko, S. (2021). Is the Younger Generation a Driving Force Toward Achieving the Sustainable Development Goals? Survey Experiments. *Journal of Cleaner Production*, *292*, 125932.

Yeung, S. K., So, W. M. W., Cheng, N. Y. I., Cheung, T. Y., & Chow, C. F. (2017). Comparing Pedagogies for Plastic Waste Management at University Level. *International Journal of Sustainability in Higher Education*, *18*(7), 1039–1059.

Zdonek, I., Podgórska, M., & Hysa, B. (2017). The Competence for Project Team Members in the Conditions of Remote Working. *Foundations of Management*, *9*(1), 213–224.