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Facilitating Students' Scientific Reasoning Skills and Sustainability Literacy in Higher Education - Needs Analysis and Suggested Model

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A B S T R A C T

Sustainable education has become one of the main goals in the sustainable development agenda. This study aims to analyze the needs in science learning. The needs analysis begins by identifying problems in science learning, followed by an analysis of the needs in science learning. This research employs a mixed-method approach with a sequential exploratory design. Data collection techniques include focus group discussions, observation, interviews, document studies, and questionnaires. Data analysis techniques use the Miles, Huberman, & Saldana model for qualitative data and descriptive methods for quantitative data analysis. The analysis results indicate the importance of facilitating scientific reasoning skills and sustainable literacy for students. The study also provides recommendations for science learning designs that can support the development of these skills

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INTRODUCTION

Scientific reasoning skills are a primary goal in science education (OECD, 2019). These skills represent a high-order thinking ability that is essential to achieve in 21st-century education because they are integral to preparing students to solve complex problems (Hasruddin & Aulia, 2023; Janssen et al., 2019; Kambeyo & Scapo, 2018). Scientific reasoning is a skill that must be developed in science learning, as it serves as a prerequisite for investigative activities (Edward et al., 2017; Stylinski et al., 2020). Scientific reasoning skills positively impact scientific knowledge because science learning, particularly in investigative activities, relies on certain prerequisite skills, including students' proficiency in scientific reasoning (Bruckermann et al., 2023). The higher a student's scientific reasoning skills, the greater their scientific knowledge (Ding et al., 2023; Moore & Rubbo, 2012).

Several studies have examined the importance of scientific reasoning skills. For example, research conducted by Bao et al. found that scientific reasoning strongly correlates with cognitive ability, serving as an effective reasoning tool in science (Bao et al., 2009). This finding is further supported by Bruckermann et al., who demonstrated that scientific reasoning skills positively impact scientific knowledge (Bruckermann et al., 2023). Students' learning outcomes improve when they engage more deeply in scientific activities (Burgess et al., 2017; Edward et al., 2017; Gray et al., 2017; Phillips et al., 2018; Stylinski et al., 2020). Conversely, low scientific reasoning skills can hinder the investigative process experienced by students and disrupt the achievement of learning outcomes (Burgess et al., 2017; Edward et al., 2017; Gray et al., 2017; Phillips et al., 2018; Stylinski et al., 2020).

However, in reality, scientific reasoning skills remain low, as highlighted in research conducted by Mariana et al. (Mariana et al., 2018). Other studies have also found that students' scientific reasoning skills are generally low. The analysis of the causes points to a lack of innovation in teaching and the failure to relate learning to the surrounding environment (Utami et al., 2020). These findings are further supported by other research indicating that most students' scientific reasoning skills fall within low to moderate criteria (Pratiwi & Alberida, 2021). Developing scientific reasoning skills at the higher education level is crucial, given the low level of scientific reasoning observed among university students, particularly prospective elementary school teachers (Koyunlu Ünlü et al., 2024). dditional research has shown that even higher-level students often lack the ability to apply scientific reasoning skills in daily life, such as drawing accurate conclusions based on evidence (Janssen et al., 2019).

The analysis results link the low level of scientific reasoning skills to insufficient development of these skills in learning activities. A well-designed and systematic learning environment can contribute to the attainment of high scientific reasoning skills (Janssen et al., 2019; Utami et al., 2020). Scientific reasoning skills can be identified in pedagogical settings where students are required to learn the scientific method during experimental activities (Bhaw et al., 2023). Engelmann et al. also explain that science learning designed through various activities can train students to develop scientific reasoning skills

(Engelmann et al., 2016). This is further supported by Suaidah et al., who state that scientific reasoning skills can be cultivated during science lessons through diverse activities (Suaidah et al., 2023).

Scientific reasoning skills can serve as a critical tool in addressing global issues, making them essential for achieving the Sustainable Development Goals (SDGs). These skills are an integral part of critical thinking (Sobari et al., 2022; Zulkipli, 2020) particularly for analyzing problems such as environmental issues based on strong evidence, enabling precise solutions to environmental challenges. Environmental issues represent a global challenge often attributed to a lack of awareness among individuals or communities about caring for the Earth. Therefore, introducing knowledge and fostering sustainable attitudes is seen as a viable solution.

Sustainability literacy refers to the understanding and attitude that enable individuals to be highly committed to building a sustainable future and to assist others in making appropriate and effective decisions toward a sustainable society (Mason, 2019). Sustainability literacy has become a key outcome in sustainable education, serving as a transitional competency toward a sustainable society (Leiva-Brondo et al., 2022; Winter & Cotton, 2012). Individuals with sustainability literacy can comprehend the symbiotic relationship between the environmental, social, and economic dimensions of sustainable development. They are also capable of integrating relevant knowledge with skills and, furthermore, recognizing and valuing sustainable actions taken by others (Ozdemir, 2023).

However, based on the analysis, students' sustainability literacy is still categorized as low. For instance, research conducted by Putri et al. found that students' sustainability literacy regarding perceptions of environmental changes falls into the low category (Putri et al., 2023). Adam et al. analyzed science learning in relation to students' sustainability literacy. Using an experimental method, they found that improvements in sustainability literacy remained in the low category, particularly in the environmental aspect (Adam et al., 2021). Other studies also support the finding of low sustainability literacy attitudes and knowledge among university students (Alkhayyal et al., 2019). Similarly, research by Fatimah et al. revealed that the sustainability literacy profile of prospective elementary school teachers still needs improvement, particularly in the aspects of sustainable attitude and behavior (Fatimah, Rahayuningsih, et al., 2024). These two aspects are closely related to the attitudes of prospective teachers toward sustainability concepts. In the aspect of sustainable attitude, the locus of control plays an important role in shaping sustainability awareness and influences pro-environmental attitudes in individuals (Siregar *et al.,* 2022).

The low level of sustainability literacy has led researchers worldwide to recommend the importance of introducing sustainability literacy in environmental issues at the higher education level. Active learning and teaching about sustainability literacy are seen as viable solutions for improving sustainability literacy (Putri et al., 2023). Teaching that emphasizes sustainability literacy is also highlighted as a crucial part of global researchers' recommendations (Alkhayyal et al., 2019; Henderson et al., 2022). Therefore,

there is a need to develop effective approaches and strategies to enhance sustainability literacy at the higher education level.

Based on the explanation above, innovations in science learning that can facilitate scientific reasoning skills and sustainability literacy are essential to develop. Therefore, this study delves deeper into the needs analysis of science learning to support these skills. The needs analysis stage ensures that the product to be designed and developed aligns with user requirements (Dewi & Fahmi, 2018; Fatimah et al., 2021; Fatimah, Rusilowati, et al., 2024). Branch highlights that needs analysis is a crucial step in product development, aimed at reducing the gap between the required competencies and existing competencies (Branch, 2009). The results of this analysis serve as recommendations for developing an appropriate science learning model to facilitate scientific reasoning skills and sustainability literacy.

LITERATURE REVIEW

Scientific Reasioning Skill

Scientific reasoning skills are cognitive abilities used to understand and evaluate scientific information. These skills involve developing hypotheses, particularly regarding how something works, and then testing those hypotheses (Zulkipli, 2020). During the reasoning process, individuals tend to relate the phenomenon being investigated to their prior knowledge, and then new knowledge is sought as the previous knowledge is corrected and integrated. Scientific reasoning is the ability to link observed phenomena to scientific theories in order to predict potential outcomes. It is used in experimental design settings, hypothesis testing, and data interpretation. Therefore, scientific reasoning consists of conceptual understanding and investigative skills (Zimmerman, 2007) to connect experimental data with theory in order to generate the best conclusions.

The conceptual framework of scientific reasoning includes three dimensions: scientific reasoning as the process of scientific discovery, scientific reasoning as the focus of scientific argumentation, and scientific reasoning in terms of understanding the nature of science (Engelmann et al., 2016). Meanwhile, Lawson provides four dimensions for exploring scientific reasoning: the conservation dimension, proportional reasoning dimension, control of variables dimension, and probability dimension (Lawson, 2004). Scientific reasoning skills are considered a high-order thinking skill and are essential to develop in the 21st century (Kambeyo & Scapo, 2018) as well as a prerequisite skill that students must possess to master scientific activities, particularly in inquiry-based learning (Edward et al., 2017; Stylinski et al., 2020).

Sustainability Literacy

Sustainability literacy is a key outcome in sustainable education, serving as a competency for the transition toward a sustainable society (Leiva-Brondo et al., 2022; Winter & Cotton, 2012). Individuals with sustainability literacy are able to understand the symbiotic relationship between the environmental, social, and economic dimensions of sustainable development. They can also integrate relevant knowledge with skills and, further, recognize and appreciate sustainable actions taken by others (Ozdemir, 2023). Sustainability literacy has four

dimensions: Sustainable Attitude (SA), Sustainable Behaviour (SB), Sustainable Knowledge (SK), and Sustainable Perception (SP). SA is divided into subdimensions such as "concern/worried," "social responsibility," and "locus of control." SB is designed with subdimensions like "consumption pattern," "household use," and "participation." The SK dimension relates to knowledge regarding environmental issues, while SP refers to students' perception of the most effective way to achieve sustainability transmission (Ozdemir, 2023).

Sustainability literacy in higher education has become one of the recommendations put forward by many researchers worldwide (Fatimah et al., 2025). This is evident as there is still a low level of sustainability literacy attitudes and knowledge among university students (Alkhayyal et al., 2019). Integrating sustainability literacy into the higher education curriculum is a recommendation widely provided by researchers around the world (e.g, (Alotaibi, 2021; Hamdan Alghamdi & El-Hassan, 2019; Jillani et al., 2022; Malik et al., 2019; Mares-Nasarre et al., 2023). This includes the development of teaching approaches and strategies that emphasize sustainability literacy (Alkhayyal et al., 2019; Henderson et al., 2022).

METHODOLOGY

Types of Research

The research is a mixed methods research with a sequential exploratory type. This approach to research involves mixing both qualitative and quantitative data collection methods and data analysis techniques (Creswell, 2014). A mixed-methods research approach provides both qualitative and quantitative evidence that gives a more complete picture of the phenomena under investigation. The subject of sustainability literacy requires research participants' opinions and statistical data to fully understand the concept. Mixed-methods research aims at drawing from the strengths of each research approach and minimizing the weaknesses of any single research studies (Johnson & Onwuegbuzie, 2004). Sequential exploratory research is research where data collection begins with qualitative data collection and then continues with quantitative data collection.

Research Subject

The subjects of this study are lecturers teaching science courses from various universities, both public and private, located in Central Java. The respondents in this study include 156 prospective elementary school teacher students. Below is the profile of the respondents based on gender.

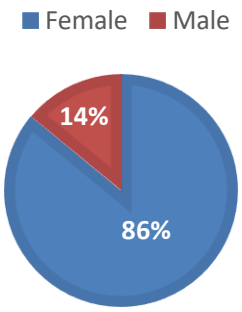

Figure 1. Respondent Profile Based on Gender

Research Instruments

Qualitative research was carried out using Focus group discuccion, observation, interviews, and documentation. FGD (Focus Group Discussion) was conducted to gather more detailed and in-depth information about the issues in science learning and to analyze the needs of lecturers teaching science courses. The FGD was conducted using a Zoom meeting. Observations were made during the implementation of science lessons. Interviews were conducted with students to explore the problems they encountered and analyze their needs during science learning. Documentation studies, such as lesson plans and students' final exam results, as well as photos of the learning process, provided important information for this study. Meanwhile, the quantitative research instrument used a questionnaire. The questionnaire employed a Likert scale with five alternative response options: Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. The questionnaire covered aspects of the issues faced by students and their needs in science learning.

Data Analysis Techniques

The validity of data in qualitative research is carried out using triangulation techniques. The data is then analyzed using the interactive analysis technique formulated by Miles, Huberman, & Saldana (Miles et al., 2014). This study utilizes the data analysis technique of Miles, Huberman, and Saldana, which consists of three stages: data condensation, data display, and conclusions. Data condensation involves collecting data first and then sorting it based on research needs. If there is data that is considered irrelevant then it is ignored. In data reduction, classification is also carried out based on variables. The data is divided into two main aspects, namely data about analysis of the need for scientific reasoning skills and sustainability literacy in higher education. The next stage is to present the data in various forms, including descriptions, tables and pictures, so that readers can understand the meaning of the research data. The final step is verification/drawing conclusions, where the existing data is summarized based on the research objectives, and overall conclusions are drawn from the conclusions of each objective. Meanwhile, quantitative research is carried out using descriptive method. The descriptive method is commonly used for survey research, and the research data is visualized in the form of graphs, charts, tables, and so on. This aims to make it easier for researchers to understand large amounts of data, allowing descriptive statistical data to be reduced into a format that is easy to digest and manage. The descriptive method allows the research to be conducted in the natural context of the respondents, not only certifying high-quality data but also representing data collection from a large population (Ghanad, 2023).

RESULTS

Need Analysis of the Scientific Reasoning Skills's Students

Based on the results of the FGD with lecturers teaching science courses, scientific reasoning skills are very important to develop because science learning is closely related to the inquiry process. The results of the FGD analysis showed that lecturers typically use inquiry-based learning and experiments. However, based on observations, lecturers still need to innovate in inquiry-based learning to allow students' skills to develop optimally. Specifically, in scientific reasoning skills such as analyzing problems, formulating hypotheses, manipulating variables, designing and conducting investigations, analyzing results, and communicating findings. Many students still struggle with determining and manipulating variables, so their creative thinking ability in conducting investigations is also low. Students prefer having a guide or lab instructions, which means they tend to be less capable of conducting more in-depth investigations. This result is consistent with survey data from students indicating that lecturers have used several methods in teaching, particularly experiments and investigations.

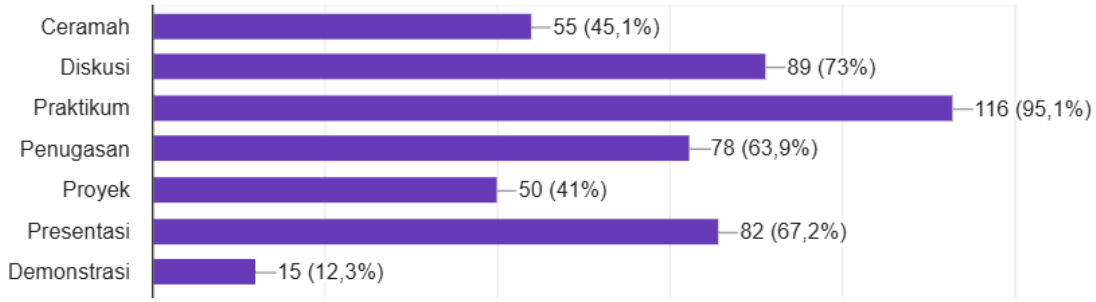

Figure 2. Respondent Results Based on the Teaching Methods Used by Lecturers During Science Learning

The results of the interviews with students showed that science learning is mostly conducted through experiments or investigations, both in the laboratory and outside the laboratory. Typically, lecturers provide problems as an introduction before students conduct investigations. This problem analysis is discussed within groups and then used as material for conducting the investigation.

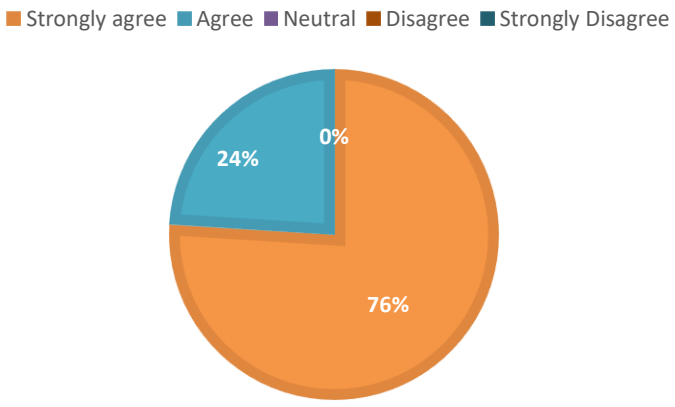

Figure 3. Student Response to Investigation Activities

Based on Figure 3, the majority of students strongly agree with the presence of investigation activities, both in the laboratory and outside the laboratory, with 76% of students strongly agreeing and 24% agreeing. This result proves that students in science learning require inquiry-based learning. According to the interview results, investigations allow students to discover and prove science concepts in a more tangible way. Compared to just lectures, students prefer investigation activities.

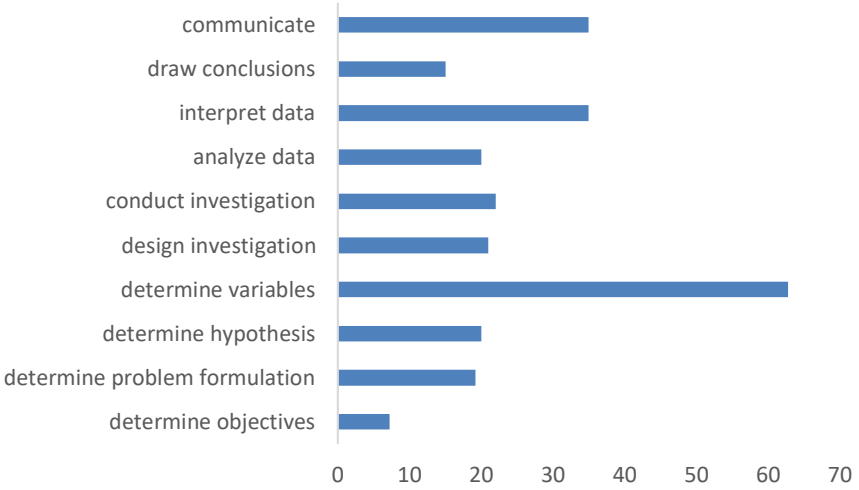

Figure 4. Student Difficulties in Investigation Activities

Figure 4 shows that the majority of students experience difficulties in investigations, particularly in determining and manipulating variables. Interpreting data is also an aspect of the investigation activity that students still find challenging. This is because they are still unable to create tables or graphs that align with the measured variables. In terms of communication, students tend to only explain the results of the investigation without using relevant references to elaborate on the findings. The search for scholarly literature, such as research articles, has not been optimized by students, leading them to provide assumptions rather than evidence-based explanations for the investigation results.

Based on the interview results, students are still not accustomed to using scholarly literature to explain the results of their investigations. They also face difficulties in conducting searches for scientific references. They believe that learning experiences that familiarize students with literature searches are important so that students can provide ideas or arguments based on scientific information.

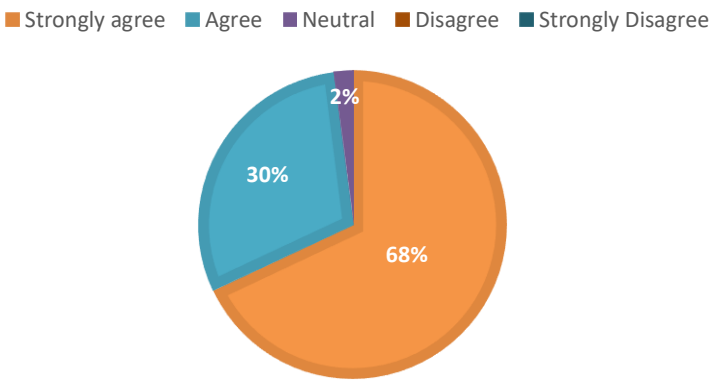

Figure 5. The Importance of Developing Skills that Support Investigation

Figure 5 shows that 68% strongly agree and 30% agree, while the remaining 2% are neutral, regarding the importance of developing skills that support investigation. These results prove that students highly need skills that can enhance investigation activities to make them more optimal and meaningful, such as the development of scientific reasoning skills. Based on the interview results, the development of scientific reasoning skills during science learning activities is very important, especially during investigative activities.

Need Analysis of Students' Sustainability Literacy

Based on the results of the FGD with science course lecturers, sustainability literacy is very important to develop in sustainable science education. The FGD analysis results indicate that sustainable learning is still rarely emphasized in science education. All lecturers agree on the importance of introducing sustainable science learning so that students develop attitudes that not only care for the environment but also for the surrounding community. During the lessons, lecturers have encouraged students to show concern for the environment. However, this has not yet become a characteristic ingrained in the students. Science learning still focuses on discussing science materials, such as explaining the concept of energy and the types of energy, without linking it to the importance of preserving energy sources and the threats posed by the use of fossil fuel-based energy. This result is also supported by a survey conducted with students, indicating that science education introducing sustainable skills is also needed by students.

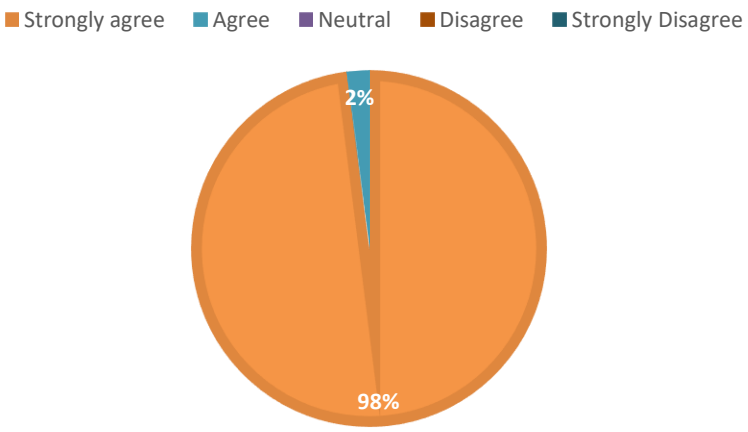

Figure 6. The Importance of Developing Sustainability Literacy in Science Education

Figure 6 shows that 98% strongly agree and 2% agree with the introduction of sustainability literacy. This proves that students need the development of sustainability literacy in science education. Based on the interview results, students are aware of the importance of protecting the environment and being concerned about the surrounding community. Therefore, students need the introduction of sustainability literacy in science education. Additionally, they still do not fully understand the deeper meaning of sustainability.

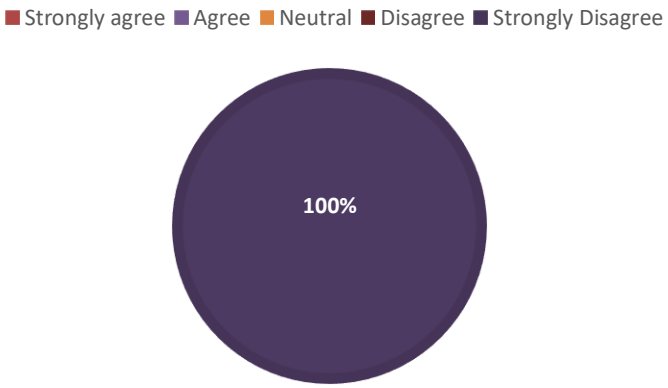

Figure 7. Students' Understanding of Sustainability

Figure 7 shows that 100% of students do not understand the concept of sustainability. They are still unfamiliar with the term sustainability. Based on the interview results, students are very interested in learning more about skills related to sustainability. According to the interview, they have only been familiar with the attitude of caring for the environment (environmental literacy), but the concept of sustainability literacy is a term they have only recently heard. Therefore, they are eager to develop sustainability literacy.

Recommendations for a Learning Model to Facilitate Scientific Reasoning Skills and Sustainability Literacy

Based on the results of the FGD, science education that can facilitate scientific reasoning skills and sustainability literacy is highly needed. All the lecturers agree that introducing sustainability literacy to students will contribute to achieving sustainable education, particularly at the higher education level. This presents a major challenge for lecturers to develop science teaching that focuses on sustainable education. Lecturers believe that with sustainable education, science learning will become more adaptive and innovative in response to global demands. Students will develop attitudes that contribute significantly to environmental conservation and social awareness. Furthermore, with the global agenda for sustainable development, science education should be oriented towards sustainability education. According to the results of the FGD, lecturers have not used any learning models oriented towards sustainability education. Therefore, science education oriented towards sustainability education should be implemented as an effort to develop sustainability literacy. These results align with the survey data, which shows that students strongly agree with having science education that fosters sustainability literacy.

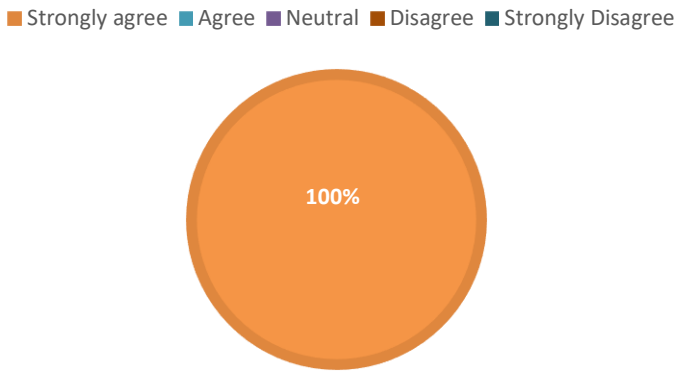

Figure 8. Students' Response to Science Education Oriented Towards Sustainability Education

Figure 8 shows that 100% of students strongly agree with science education oriented towards the development of sustainability literacy. So far, science education has been limited to discussions and investigations that have not yet focused on sustainability education.

During the FGD, the researcher conducted an in-depth analysis of the resources needed by lecturers to facilitate students' scientific reasoning skills and sustainability literacy. The results of the FGD showed that lecturers need a learning model design that promotes the development of students' scientific reasoning skills and sustainability literacy. This learning model design should be equipped with a lesson plan, guidelines for using the learning model, and instruments to assess scientific reasoning skills and sustainability literacy. So far, lecturers have mostly used inquiry-based learning, and they hope that the developed learning model will still be inquiry-based since students are already accustomed to investigative activities. To make inquiry-based learning more

meaningful, science education can focus on argumentation activities using scientific literature sources.

The FGD resulted in a discussion about the design of science education that focuses on argument-driven inquiry based on local wisdom and STEM. Lecturers strongly agree with the introduction of argument-driven inquiry that is oriented toward local wisdom and STEM. Through investigations supported by scientific argumentation, students can develop better scientific reasoning skills. By introducing local wisdom, students can understand science concepts more deeply from a different perspective, enabling them to develop critical and creative thinking skills. Additionally, by engaging with local wisdom, students interact more with the environment and the surrounding community, which is expected to facilitate the development of scientific reasoning skills and sustainability literacy effectively. Through STEM, students are introduced to the use of technology and tools that are environmentally friendly.

DISCUSSION

The FGD results show that science lecturers require the development of scientific reasoning skills that can optimize science inquiry activities. Scientific reasoning skills have proven to make inquiry activities more meaningful, which in turn impacts students' understanding. This finding is consistent with the research conducted by Bruckermann et al., which indicates that scientific reasoning skills positively affect scientific knowledge because science learning, especially in inquiry activities, relies on certain prerequisite skills, such as students' proficiency in scientific reasoning (Bruckermann et al., 2023). The higher the scientific reasoning skills of students, the greater the scientific knowledge they possess (Ding et al., 2023; Moore & Rubbo, 2012).

The survey results from students reinforce the findings of the FGD, with 98% strongly agreeing on the importance of developing scientific reasoning skills in science education, particularly in inquiry activities. The majority of students still struggle with determining and manipulating variables, which affects subsequent stages of inquiry and significantly increases the likelihood of obtaining incorrect data, making it impossible to draw accurate conclusions. It is believed that having scientific reasoning skills will ease students in conducting inquiries. This result aligns with previous research, which indicates that scientific reasoning skills help students understand and evaluate scientific information, allowing them to make accurate conclusions and decisions (Suaidah et al., 2023; Yanto et al., 2019).

In addition to scientific reasoning skills, the development of sustainability literacy is crucial to strengthen in science education. The development of sustainability literacy aims to achieve sustainable education within science learning. This is important to develop, especially at the higher education level. The survey results from students support the FGD findings, with 100% of students agreeing with the introduction and development of sustainability literacy. This result aligns with research conducted by several previous scholars, which emphasizes the importance of introducing sustainability literacy to

university students to help them develop a positive attitude toward the environment (Alkhayyal et al., 2019; Syed Azhar et al., 2022).

Science education that focuses on argument-driven inquiry (ADI) based on EthnoSTEM is a recommendation for facilitating students' scientific reasoning skills and sustainability literacy. The ADI model has been proven to facilitate and enhance scientific reasoning skills (Atqiya et al., 2021; Inthaud et al., 2019). Engaging in argumentation, both orally and in writing, is key to training and developing scientific reasoning skills. This means that scientific reasoning skills support students in making scientific arguments. Therefore, these two skills are correlated (Thoron, 2010). Other findings also indicate that the ADI model has an impact on students' metacognitive awareness (Erenler & Cetin, 2019). Metacognitive skills are believed to support the development of scientific reasoning skills (Haryani et al., 2018; Setiawan & Supiandi, 2018; Yurttaş Kumlu & Şahin, 2022).

Students will find it easier to understand contextual problems in their surrounding environment through the introduction of diverse local wisdom (Kundariati *et al.,* 2022; Shofiyah *et al.,* 2019). The EthnoSTEM approach has a more significant impact by integrating STEM. Research shows that through STEM, scientific reasoning skills can be well developed (Koes-H & Putri, 2021; Lorensia *et al.,* 2024). Additionally, STEM is an important approach for developing 21st-century skills and is recommended by UNESCO for sustainable education (Chan & Nagatomo, 2021; Wahono et al., 2020) and enables students to solve problems more effectively (Sumarni & Kadarwati, 2020).

CONCLUSIONS AND RECOMMENDATIONS

Based on the research results, it can be concluded that the FGD results indicate that lecturers agree that science education needs to further develop scientific reasoning skills and also start to introduce and develop sustainability literacy as an effort to realize sustainable education. The survey results show that 98% of students strongly agree that scientific reasoning skills are important in science education, especially during the investigation process. Additionally, 100% of students strongly agree that sustainability literacy should be developed in science education. Based on the FGD results, there is a need for a science education design that focuses on investigation activities, with an emphasis on scientific argumentation and the importance of introducing local wisdom in science education. Furthermore, the introduction of environmentally friendly technologies or tools is highly recommended in science education. The research results suggest a recommendation for future research, namely the development of a science education model design that uses the argument-driven inquiry approach based on Ethno-STEM.

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