Scientific Argumentation Based on the Toulmin Argumentation Pattern and Environmental Attitudes among Junior High School Students

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Abstract
Scientific argumentation skills are an important competency in 21st century learning because they help students critically evaluate environmental issues, make evidence-based decisions, and form an attitude of caring for the environment. This study aims to analyze scientific argumentation skills, environmental concerns, and the relationship between the two in junior high school students. The research uses a quantitative approach with a correlational descriptive design. The sample consisted of 32 grade VIII students who were selected using the purposive sampling technique. Data were collected through scientific argumentation ability tests based on the Toulmin Argumentation Pattern (TAP), environmental care attitudes questionnaire based on Ugulu indicators, and observation sheets. Data analysis was carried out using descriptive statistics and Pearson correlation test. The results showed that students' scientific argumentation skills were in the low category (M = 51.74). The claim component obtained the highest scores, while warrants, backing, rebuttals, and qualifiers were still low. Environmental care is also in the less category (M = 2.20). The correlation test showed a strong and significant positive relationship between scientific argumentation ability and environmental concern ($r = 0.740$; $p < 0.001$). These findings show that improving scientific argumentation skills has the potential to support the development of environmental care attitudes. Therefore, science learning needs to integrate the Socio-Scientific Issues (SSI) and Education for Sustainable Development (ESD) approaches.

1. Introduction

The ability to think critically, argumentatively, and concern for global problems, including environmental issues, is indispensable in the development of the 21st century era (Mardhiyah et al., 2021; Sari et al., 2025). The ability to scientific argumentation is one of the important competencies in the context of science learning (Altun & Ozsevgec, 2025; Yeh et al., 2021). Scientific argumentation allows students to formulate claims, use evidence, and evaluate information rationally (Zhou, 2024). Research on sustainability-based argument-driven inquiry shows that argumentation activities can support the development of students' critical thinking skills in dealing with environmental and sustainability problems (Khoiri et al., 2022). This ability is needed so that students are able to make science-based decisions on various real problems faced by society, especially environmental problems that are increasingly complex (Cooke et al., 2023; Hemming et al., 2022).

Various studies show that students' scientific argumentation skills are still not developed optimally and in the low category (Nirmala et al., 2026). Most student's express opinions without being supported by strong evidence and reasoning (Hendratmoko et al., 2023; Seifert et al., 2022). This problem is also found in higher levels of education, which shows that the low ability of scientific argumentation is systemic (Kuhn & Modrek, 2022). Low scientific argumentation skills cause students to have difficulty critically analyzing environmental issues and making logical decisions based on scientific evidence (Faize & Akhtar, 2020; Shasha-Sharf & Tal, 2023).

Environmental issues are currently an urgent global challenge because they are related to pollution, ecosystem damage, climate change, and declining quality of life (Hadiapurwa et al., 2024; Sikdar, 2021; Ukaogo et al., 2020). Therefore, education plays an important role in building environmental awareness and responsibility from an early age (Aldawsari et al., 2025; Hnatyuk et al., 2024). In science learning, an attitude of caring for the environment is an affective aspect that needs to be developed so that students are able to show behavior that is responsible for environmental sustainability, not only theoretically (Ikhsan et al., 2025;

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Ratnasari et al., 2024). Environmental attitudes is important because students' low environmental concern can underlie the emergence of destructive behavior and lack of preservation of the surrounding environment (Shafiei & Maleksaeidi, 2020; Yonanda et al., 2026).

Some studies show that the attitude of caring for the environment is still in the early stages, i.e. students show awareness but have not been followed by real behavior (Alharbi et al., 2025; Qodriyanti et al., 2022; Warni et al., 2022). Students generally understand the importance of protecting the environment but are not used to implementing environmentally caring behaviors consistently in their daily lives (Algurén, 2025; Chen et al., 2025). This condition shows that science learning has not been fully able to integrate the development of scientific thinking skills with the formation of environmental attitudes character (Ashlan & Firayani, 2025; Yazidi & Rijal, 2024).

Studies on scientific argumentation skills and environmental concerns have been widely conducted, but most studies still place the two variables separately (Hendratmoko et al., 2023; Khishfe, 2022; Rawe et al., 2025; Sari et al., 2025). In fact, conceptually these two aspects are interrelated, where the ability to scientific argumentation can help students evaluate information, consider various points of view, and make science-based decisions on environmental issues (Handayani, 2025; Rahayu et al., 2022). Previous research has shown that learning that involves argumentative activities and discussions about sustainability issues can increase students' sustainability awareness (Hayat et al., 2025). Students with good argumentation skills are expected not only to be able to understand environmental problems but also have awareness and responsibility in determining attitudes towards the environment (Kristensen & Knain, 2024). Therefore, a study that integrates these two aspects is needed to obtain a more comprehensive picture.

Based on this description, the research questions in this study are: (1) how students' scientific argumentation skills based on the Toulmin Argumentation Pattern (TAP), (2) how students' environmental attitudes, and (3) how is the relationship between students' scientific argumentation skills and environmental attitudes. The objectives of this study are (1) to analyze scientific argumentation skills, (2) to analyze students' environmental attitudes, and (3) to analyze the relationship between scientific argumentation skills and students' environmental attitudes.

2. Method

This study uses a correlational descriptive quantitative approach with the aim of describing students' scientific argumentation skills and environmental concerns, as well as analyzing the relationship between the two variables. The descriptive approach was used to obtain an overview of the profile of scientific argumentation ability and the attitude of caring for the environment of students, while the correlational approach was used to determine the close relationship between the two variables. The research was carried out in the even semester of the 2025/2026 school year.

The research population is all grade VIII students who have studied ecology and environmental conservation materials. The research sample was determined using the purposive sampling technique by considering the representation of student characteristics and the feasibility of the research. The sample consisted of 32 grade VIII students who had heterogeneous academic ability characteristics.

The research instruments consisted of scientific argumentation ability tests, environmental attitudes questionnaires, and observation sheets. A scientific argumentation ability test developed based on the Toulmin Argumentation Pattern (TAP) which includes claims components, data, warrants, backing, rebuttals, and qualifiers. The test instrument consists of four description questions prepared using the context of local environmental issues in the form of the development of the Batang Integrated Industrial Estate (KITB). Scoring of scientific argumentation skills was carried out using an analytical rubric based on the TAP component which included claims, data, warrants, backing, rebuttal, and qualifier components. Each component is scored 1–4 based on the level of completeness and accuracy of the arguments presented by the students. The scoring rubric is adapted from the Toulmin Argumentation Pattern framework which has been used in various scientific argumentation studies (Osborne et al., 2004); Sampson & Clark, 2008). The total argumentation score is obtained from the accumulation of scores of all TAP components and is used to describe the profile of students' scientific argumentation ability.

Environmental attitudes were measured using a questionnaire compiled based on indicators Ugulu (2013) which includes environmental awareness, attitudes towards recovery, attitudes towards recycling, and environmental consciousness and behavior. The questionnaire consisted of 20 positive and negative statements with a choice of always, often, rarely, never. In addition, observation sheets are used to strengthen test and questionnaire data through direct observation of student behavior during the learning process and activities in the school environment.

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The results of the test validity test show that all question items have an item-total correlation value greater than the r-value of the table (0.349) with a significance value of less than 0.05 so that all items are declared valid. The reliability test showed a Cronbach's Alpha value of 0.878, including the high category. The item-total correlation value on the environmental attitudes attitude instrument ranged from 0.363 to 0.730 and all met the validity criteria. The results of the questionnaire reliability test showed a Cronbach's Alpha value of 0.869 which can be interpreted that the instrument has excellent consistency and is suitable for use in the study.

Data collection was carried out by scientific argumentation tests, the dissemination of environmental attitudes questionnaires, and observation of student behavior during science learning. Tests and questionnaires are given to students after completing ecology and environmental conservation materials. This is done to ensure that all respondents have relatively the same knowledge. The data was analyzed using descriptive statistics. Statistical analysis is carried out by calculating the maximum score value, minimum score, average, percentage, and standard deviation to determine the distribution of data. Scientific argumentation skills are analyzed based on the components of TAP. Environmental attitudes are analyzed through the average score of each indicator. The interpretation of the category of attitude of caring for the environment is determined based on the four-level Likert scale score interval which refers to the principle of categorization of attitude scores according to Azwar (2012), namely very less (1.00–1.75), less (1.76–2.50), enough (2.51–3.25), and good (3.26–4.00).

Before the correlation test was carried out, the data on scientific argumentation ability and environmental concern were first tested for normality using the Shapiro-Wilk test. The results of the normality test showed that the data on scientific argumentation ability ($p = 0.440$) and environmental attitudes ($p = 0.325$) were distributed normally because the significance value was greater than 0.05. Therefore, the relationship between scientific argumentation ability and environmental concern is analyzed using the Pearson correlation test. The interpretation of relationship strength refers to the categories of correlation coefficients, namely very weak (0.00–0.19), weak (0.20–0.39), medium (0.40–0.59), strong (0.60–0.79), and very strong (0.80–1.00).

3. Results and Discussion

3.1. Scientific Argumentation Skills

The ability of scientific argumentation in this study was measured using tests and observations. Table 2 presents the results of a descriptive analysis of students' scientific argumentation skills. The results of the study showed that students' scientific argumentation skills were in the low category, with an average total test score of 51.74 or equivalent to 53.61%. Based on the interpretation criteria used, the achievement percentage of 53.61% shows that students' scientific argumentation skills are still in the low category. The standard deviation value of 3.090 shows that students' scientific argumentation skills tend to be homogeneous, so the difference in ability between students is not too large. Most students have scores that are around the average grade. This condition indicates that students' scientific argumentation skills are relatively uniform at the same level.

Table 2. Descriptive Statistics of Scientific Argumentation Ability

Statistics	Value
Number of Samples (N)	32
Average	51.74
Standard Deviation	3.090
Score Maximum	66
Score Minimum	46
Percentage of Reach	53.61%

The results of observation of students' scientific argumentation skills show that most students are in the low category. Based on the assessment criteria, 21 students (70.00%) were in the low category, 8 students (26.67%) were in the medium category, and 1 student (3.33%) was in the high category. There are no students who are in the very high or very low categories. These findings show that most students have been able to convey simple opinions and reasons but have not been able to develop a complete scientific argument with evidence, reasoning, and rebuttal in depth. The results of these observations support the test data which shows that students' scientific argumentation skills are still not developed optimally.

When viewed based on the Toulmin Argumentation Pattern (TAP) pattern, only the claim component reached the high category with an average score of 3.26, while the other components showed a gradual decline to the low category, with an overall average of 1.93. The average score of each TAP component is presented in Table 3. This pattern does not merely show a general weakness, but indicates a structural imbalance in students' thinking ability, namely strong in the expression of opinions, but weak in justification and evaluation. In the claim component, students are generally able to express their opinions on the issues given, but they are still normative and not context-based. Most students use a uniform sentence pattern without including references to concrete situations. For example, in certain industries, specific impacts, or environmental conditions around

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them. This pattern indicates that students' knowledge still does not build claims based on the results of contextual understanding.

Table 3. Average Score of Each Component of the Toulmin Argumentation Pattern (TAP)

TAP Components	TAP Maximum Score	Average	Standard Deviation	Category
Claim	4	3.26	0.58	Good
Data	4	2.41	0.64	Less
Warrant	4	1.87	0.71	Less
Backing	4	1.52	0.62	Very Less
Rebuttal	4	1.33	0.49	Very Less
Qualifier	4	1.21	0.43	Very Less
Average Total	4	1.93	0.58	Less

The absence of significant variation in claims between students also shows that their thinking ability is still at the level of remembering and identifying the information that has been learned, not yet at the level of analysis and evaluation. This is also reinforced by the lack of use of keywords that indicate critical thinking processes, such as "if", "under certain conditions", or "depending on" that should appear when students begin to consider the answer to an issue.

Quantitatively, the claim component is in the high category, but the quality of the claims submitted is still relatively low. This is because the ability to express opinions has not been followed by meaningful, contextual, and critical thinking-based claims. These findings confirm that students still need direction to build claims that are supported by a deep understanding and relevant to the context.

The research findings on the data component show that students are starting to try to provide supporting reasons for the claims they are making. Although the quality of the data used is still superficial and general. The statement provided shows that students recognize the basic relationship between industrial activity and environmental impact but have not been able to provide data as specific and contextual scientific evidence. This is in line with the finding that students often have difficulty distinguishing between opinion and scientific evidence (Faize & Akhtar, 2020; He et al., 2020).

This condition indicates that students do not understand the function of data as a support, but only as a complement to the narrative of the claim. The data used is less likely to have the power to strengthen the argument. This shows a low ability to select, interpret, and use evidence appropriately in support of claims.

The effective use of data in argumentation demands the ability to select, evaluate, and integrate evidence critically (Chen et al., 2025; Osborne et al., 2004). However, the use of data by students is still at the stage of surface representation, not yet at the stage of elaboration or integration. Students are not yet able to relate data to relevant scientific concepts, so data does not function as a reinforcement of arguments, but only as additional statements that are descriptive.

According to Osborne et al. (2004) and Duschl and Osborne (2002), warrants are at the heart of scientific argumentation because they serve as a link between evidence and claims. The research findings show that most students are unable to explain the logical relationship between the data and the claims they make. When asked to relate the two, students tend to give answers that are tautological or repetitive, without explaining the underlying cause-and-effect mechanisms.

The weakness of warrants shows that students have not yet understood that scientific arguments not only require evidence but also require a linking principle that explains the relevance of the evidence to a claim. Without a warrant, the argument becomes incoherent and loses its persuasive power. These findings also reflect that students' knowledge is still inert knowledge, i.e. it cannot be used flexibly in new contexts (Redman et al., 2021). Students may have studied the concept of pollution or ecosystems but have not been able to use them to explain cause-and-effect relationships in a real context. This condition reflects that learning has not emphasized the importance of reasoning as part of the scientific process. Students are more often asked to "answer correctly" than "explain why", so warrant abilities are not optimally developed.

In the backing component, almost all students did not show the use of scientific concepts as the basis for strengthening arguments. In fact, quality scientific argumentation requires integration between conceptual knowledge and reasoning (Evagorou & Dillon, 2011; Ke et al., 2021). However, in this study, no reference was found to science principles such as the material cycle, ecosystem balance, or environmental change. This condition shows that students have not achieved the ability to connect various concepts in building a complete understanding. As a result, the resulting arguments lack conceptual depth.

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The rebuttal component shows that students' answers tend to view knowledge as something definite and indisputable. In fact, rebuttal is the main indicator of critical thinking because it reflects evaluative and reflective abilities (Chen et al., 2025). From a critical thinking perspective, the ability to provide rebuttals is very important because it shows that students are able to evaluate arguments, consider other opinions, and identify weaknesses in a statement. However, in this study, students have not shown this ability, so it can be said that they have not reached the stage of evaluative thinking. These findings are in line with research showing that students tend to avoid cognitive conflict and prefer a single answer that is considered correct (Evagorou & Dillon, 2011).

In the *qualifier* component, students tend to use absolute statements such as "definitely", "always", or "all". No use of words was found indicating a certain level of belief or condition, such as "likely", "under certain conditions", or "mostly". In fact, according to He et al. (2020) and Faize et al. (2017), the use of qualifiers reflects the understanding that scientific knowledge is probabilistic and contextual.

This condition shows that students still view knowledge as something certain and unchanged. This way of thinking can be an obstacle in developing more open and flexible scientific thinking. In addition, the ability to use a qualifier is also related to the ability of students to be aware of the limitations of the knowledge they have. The low use of qualifiers indicates that students are not used to reflecting on how confident they are in the arguments made, so the arguments presented tend to be rigid and lack depth.

Low scores on the warrant, backing, rebuttal, and qualifier components indicate that students have not fully mastered the complex structure of scientific argumentation. Theoretically, these four components require high-level thinking skills because students are not only asked to express opinions, but also relate evidence to claims, use scientific concepts as a basis for reasoning, evaluate alternative arguments, and consider the limitations of a statement. This ability is related to the process of analysis, evaluation, and reflection which is at a higher cognitive level than the ability to make a claim. In science learning practice, students are more often trained to answer questions with one correct answer rather than building arguments that are open to multiple perspectives. This condition causes the development of argumentation skills to be unbalanced, namely relatively good in the delivery of opinions, but still weak in the aspects of justification and evaluation.

The high score on the claim component shows that students are relatively able to express their opinions on the given environmental issues. Conversely, low rebuttal and qualifier scores indicate that students still have difficulty evaluating alternative arguments and placing limits on the claims made. This condition shows that students' argumentative skills are still in the early stages, namely being able to express opinions but are not used to doing critical reasoning that involves evaluating various perspectives. Similar findings by Rawe et al. (2025) who found that the rebuttal and qualifier components were the most difficult part of the argument to be developed by students.

This condition also shows that the learning process that takes place has not encouraged students to discuss or debate scientifically. Students tend to accept information as it is and are rarely trained to question or criticize an opinion. As a result, students' ability to build complete and in-depth arguments has not been optimally developed. When compared to previous research, this pattern is consistent with the finding that students tend to stop at claims and data, without developing a more complex argumentation structure. However, this study makes an additional contribution by showing that these weaknesses are systemic and occur in all advanced components, not just in one specific aspect.

Overall, the weakness in all components of Toulmin shows that the student's argument has not yet developed into a complete system of scientific thinking. These findings are in line with research showing that students are often only able to achieve claims and data, without being able to develop more complex argumentation structures (Chen et al., 2025; Osborne et al., 2004). Furthermore, this condition reflects that students have not experienced the process of getting used to thinking like scientists through the practice of argumentation (Duschl & Osborne, 2002).

In the context of environmental education, this low argumentation ability has an impact on students' inability to understand the complexity of environmental issues, so that the attitudes formed are only superficial. This reinforces the finding that scientific argumentation has an important role in decision-making based on environmental issues (Ke et al., 2021; Evagorou & Dillon, 2011). The low ability of scientific argumentation can affect students' ability to critically evaluate environmental issues so that students' environmental attitudes attitudes have not developed optimally and tend to still be situational.

3.2. Attitude of Caring for the Environment

Based on the results of the environmental attitudes attitude questionnaire, most students are in the categories of sufficient, less and very poor. A total of 3 students (9.37%) were in the sufficient category, 21 students (65.63%) were in the poor category, and 8 students (25%) were in the very poor category. There are no students who are in the category of good, or very good. These results show that students' attitude of caring

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for the environment is still low and has not developed optimally. This condition indicates that students have a basic awareness of the importance of protecting the environment but have not been able to internalize it in the form of real and consistent behavior in daily life.

The findings were strengthened by the results of observations of students' environmental attitudes behavior at school. The results of the observation showed that 40.67% of students were in the very poor category and 59.37% were in the poor category. This observation data shows that the real behavior of students in protecting the environment, such as disposing of garbage in its place, saving water and electricity use, and maintaining the cleanliness of the school environment, is still relatively low.

In addition to the overall category, an analysis of students' environmental attitudes attitudes was also carried out on each indicator to find out the most prominent aspects and aspects that still need to be improved. The average distribution of scores in each indicator of environmental care is presented in Figure 1. Based on the results of the analysis of the average score of each indicator, it is known that most of the indicators are in the poor category. The average attitude of caring for the environment of students is at a score of around 2.2 out of a maximum score of 4 with a less category. The findings show that students' attitude of caring for the environment is still lacking, both in terms of awareness, concern for environmental restoration, recycling behavior, and real behavior in protecting the environment.

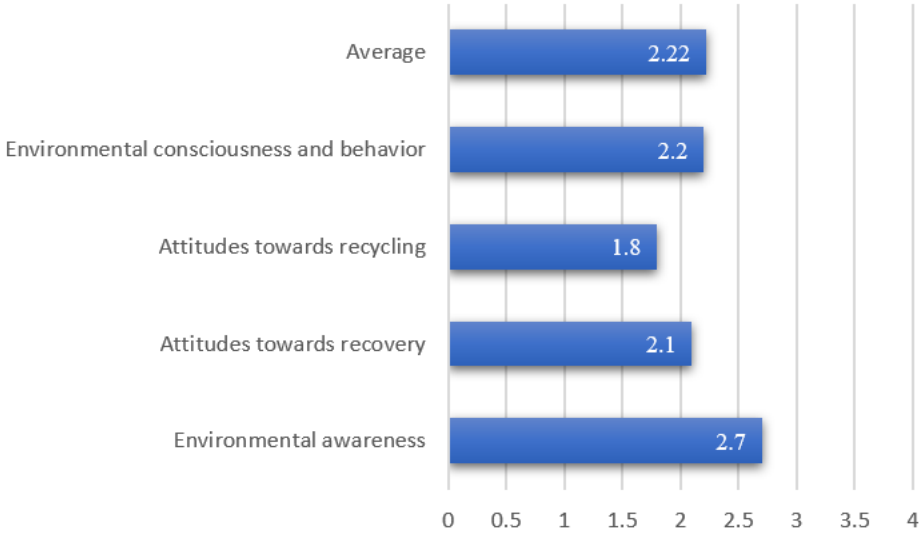

Figure. 1. Average Distribution of Environmental Attitudes of Each Component

On the environmental awareness indicator, students show a fairly good verbal understanding that the environment must be maintained. However, observational findings show that there is a gap between what is said and what students do. Students who in the questionnaire stated the importance of maintaining environmental cleanliness, in fact still throw garbage carelessly when not supervised. This shows that the consciousness possessed is still normative and declarative, that is, limited to knowing and agreeing to these values, but has not yet reached the stage of reflective consciousness that encourages real action. In other words, students have not made the value of caring for the environment part of considerations in their daily behavior.

This phenomenon is in line with the concept of the value-action gap, where individuals have awareness but are not always manifested in behavior (Evans et al., 2017; Kollmuss & Agyeman, 2002). Other research has also shown that students' environmental awareness often stops at the cognitive level without consistent behavioral changes (Qodriyanti et al., 2022; Warni et al., 2022).

In the environmental recovery indicator, students are seen participating in activities such as community service or cleaning the school environment. However, such participation tends to arise when there are instructions from teachers or school rules. When there is no direction, students rarely show the initiative to perform similar actions independently.

This shows that students' behavior is still driven by external motivations, not self-awareness. This condition is in accordance with the findings Herlina et al. (2025) which shows that students' attitudes of caring for the environment are often influenced by situational factors and have not been an internal motivation. In addition, Mawaddah et al. (2025) affirms that without learning that provides a direct and reflective experience, students tend to just follow directions without understanding the meaning of the actions taken. Thus, student involvement does not yet reflect commitment but is still at the stage of responding.

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In the recycling indicator, the most prominent weakness was found compared to other indicators. Not only do students rarely practice recycling, but they also do not have a sufficient understanding of the importance of waste management. Many students don't sort waste and don't know how to simple ways to recycle. The low recycling indicators indicate that students' knowledge of the environment has not been fully realized in concrete actions.

These findings indicate a gap between environmental awareness and environmental behavior. Students may have understood the importance of taking care of the environment but have not gained enough experience to consistently implement eco-friendly behaviors. These conditions demonstrate the importance of experiential learning and environmental projects that allow students to be directly involved in waste management and recycling activities. These findings are in line with research Arisma et al. (2024) which states that the low recycling practices are due to a lack of hands-on experience in environment-based learning. In addition, Butar-Butar et al. (2025) it also found that even if schools have implemented environmental programs, without active student involvement, behaviors will not be formed sustainably.

In the environmental behavior indicators, students' actions are still situational and inconsistent. Students tend to show environmentally caring behavior only under certain conditions, such as when they are at school or when there is supervision from teachers. Outside of these situations, such behavior does not always appear. This shows that the value of caring for the environment has not been integrated in the student's personal value system and has not become a habit.

This condition reinforces the findings Warni et al. (2022) which states that students' environmental attitudes behavior often has not reached the characterization stage, unless it is still at the level of responding. In addition, Redman et al. (2021) emphasizing that internalizing environmental values requires a continuous and contextual learning experience, not just the delivery of information. Thus, the behavior shown does not reflect a stable character, but rather still depends on the context and situation.

This condition shows that the formation of an attitude of caring for the environment does not stop at increasing knowledge or awareness but requires a process of internalizing values through repeated experiences. According to Krathwohl's affective taxonomy, the development of attitudes takes place gradually starting from receiving, responding, valuing, organization, to characterization. The results of this study indicate that most students are still at the responding stage, i.e. they have given a positive response to environmental issues, but these values have not become part of the habit that is carried out independently. Therefore, learning that is only oriented towards mastering concepts is not enough to form consistent environmental awareness.

Overall, these four indicators show that students are still in the early stages of developing environmental attitudes, namely the responding stage in affective taxonomy. Students have shown concern and response to environmental issues but have not internalized these values into a consistent habit. These findings reinforce the gap between knowledge, attitudes, and actions. Therefore, learning needs to be designed not only to increase knowledge, but also to provide direct experience, habituation, and deep reflection so that the value of caring for the environment can develop into a sustainable character.

3.3. The Relationship between Scientific Argumentation Skills and Environmental Attitudes

The results of the correlation test showed a strong positive relationship between scientific argumentation skills and students' environmental attitudes. The positive relationship indicates that the higher the student's scientific argumentation ability, the higher the attitude of caring for the environment. In contrast, students who have low scientific argumentation skills tend to show lower levels of environmental concern. These findings show that scientific argumentation skills are not only related to cognitive aspects but also related to the formation of attitudes towards the environment.

The magnitude of the correlation value shows that scientific argumentation skills have an important role in shaping the way students understand and respond to environmental problems. Students who are able to formulate claims, use evidence, build reasoning, and evaluate various perspectives tend to be better able to understand the consequences of an action on the environment. This ability allows students to assess an environmental issue more objectively and evidence-based so as to encourage the emergence of concern for the environment. In the context of the development of the Batang Integrated Industrial Estate (KITB), students who have better argumentative skills tend to be able to consider the economic benefits as well as environmental risks that may arise. In contrast, students with low argumentation tend to give simpler assessments and consider less of the various possible impacts.

The results of this study were strengthened by the value of the determination coefficient ($R^2 = 0.548$). This value shows that scientific argumentation ability has an effect of 54.8% on the variation of students' environmental attitudes, while the remaining 45.2% is influenced by other factors outside of the research, such

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as learning experience, family environment, school culture, peer influence, and exposure to information from the media. This shows that the ability to scientific argument is one of the important factors that affect the formation of an attitude of caring for the environment, although it is not the only factor.

The interconnectedness of the two is explained through the role of scientific argumentation in the evidence-based decision-making process. Students who have better scientific argumentation skills tend to be able to evaluate information, assess the reliability of evidence, and consider the consequences of an action on the environment. This ability helps students understand the impact of various environmental problems more rationally so as to encourage the formation of a more caring attitude towards the environment. These findings are in line with Faize and Akhtar (2020), scientific argumentation contributes to the formation of students' environmental knowledge and attitudes.

This relationship can be understood through the perspective of science literacy which views scientific arguments as a reasoning process in evidence-based decision-making. Students who are able to evaluate evidence, compare alternative explanations, and consider the consequences of a decision tend to have a deeper understanding of the complexity of environmental issues. This understanding is related to the formation of a more rational assessment of the importance of protecting the environment so that it is associated with a higher attitude of caring for the environment. Thus, scientific argumentation ability can be seen as one of the cognitive abilities related to attitude formation, although this study is not designed to prove cause-and-effect relationships.

Theoretically, the results of this study are in line with the view that scientific argumentation is an important part of the scientific decision-making process. According to Ke et al. (2021), Argumentative skills help students evaluate scientific evidence, consider alternative solutions, and make responsible decisions on socioscientific issues. Evagorou and Dillon (2011) also explains that scientific argumentation acts as a link between scientific knowledge and decision-making. Therefore, students who have good argumentation skills tend to be better able to understand the complexity of environmental issues and show a higher concern for environmental sustainability.

These findings also support the results Kristensen and Knain (2024) which shows that students' involvement in argumentation activities can help them build concern and an attitude of responsibility towards environmental issues. Through the argumentation process, students not only learn to express opinions, but also learn to consider the consequences of an action based on the available evidence. In addition, Khishfe (2022) It shows that scientific argumentation in integrated learning of socioscientific issues can improve students' ability to critically evaluate environmental issues and encourage the formation of a more positive attitude towards the environment.

The findings of the relationship in this study can also be explained through the results of previous descriptive analysis. Students' scientific argumentation skills are still dominant in the submission of simple claims and reasons. At the same time, students' attitude of caring for the environment is also in the category of lacking. This shows that students' limitations in using evidence, connecting data with scientific concepts, and evaluating from several perspectives can affect the way students understand environmental problems. As a result, the care that is formed has not become a consistent behavior.

These findings strengthen the suspicion that low scientific argumentation skills have the potential to be one of the causes of students' low environmental attitudes attitudes. Students who are not able to reason about the causal relationship of an environmental problem tend to only understand environmental issues at the surface level. Conversely, students who are able to develop evidence-based arguments are more likely to understand environmental impacts in depth so that they are more motivated to show concern for the environment. Therefore, the development of scientific argumentation skills needs to be a concern in science learning because it not only contributes to improving scientific thinking skills, but also to the formation of an attitude of caring for the environment.

3.4. Implication

The results of this study imply that science learning needs to be designed in a more argumentative and contextual way through the Socio-Scientific Issues (SSI) and Education for Sustainable Development (ESD) approaches. Learning that involves discussion, scientific debate, analysis of local environmental issues, and evaluation of alternative solutions can help students develop argumentative skills while building concern for the environment. Thus, science learning is not only oriented towards mastering concepts but also contributes to forming citizens who are able to think critically and be responsible for environmental sustainability.

3.5. Limitations

This research has several limitations that need to be considered in interpreting the research results. First, the study was conducted with a relatively small sample of 32 eighth-grade students from a single class, limiting

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the generalizability of the findings to other educational contexts. Second, a research design that is descriptive and correlation is only able to show the relationship between scientific argumentation skills and environmental attitudes without explaining the cause-effect relationship. Third, measuring attitudes of caring for the environment using self-report questionnaires has the potential to cause social bias because students tend to give answers that are considered good. Fourth, behavioral observations are carried out in a limited context and time so that they do not fully represent students' behavior in daily life. In addition, this study has not examined other factors that can affect scientific argumentation skills and environmental attitudes, such as the family environment, school culture, and previous learning experiences.

4. Conclusion

This study shows that students' scientific argumentation skills are still in the low category, especially in the warrant, backing, rebuttal, and qualifier components, while the claim and data components obtain better achievements. Students' attitude of caring for the environment is also relatively low, with the environmental awareness indicator having the highest score, while the attitude towards recycling is the lowest indicator. The results of the correlation test showed a strong and significant positive relationship between scientific argumentation ability and environmental concerns, indicating that students with better scientific argumentation skills tended to have higher environmental concerns. These findings confirm that the development of scientific argumentation skills needs to be an important part of science learning through the context of environmental issues and the Socio-Scientific Issues (SSI) and Education for Sustainable Development (ESD) approaches to support the formation of sustainable environmental attitudes.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/ or publication of this article.

Data Availability

The datasets generated during and/ or analyzed during the current study are available from the corresponding author on reasonable request.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript.

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