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Article

Argumentation and Decision-Making of Generation Z Pre-Service Science Teachers on Energy-Related Socioscientific IssuesHaryanti Putri Rizal^{1*}, Saeful Bahri², Marlina Ummas Genisa³, Hasri⁴, Aulia Rahmadhani⁵^{1,5}Universitas Sulawesi Barat, Indonesia²Ritsumeikan University, Japan³Universitas Muhammadiyah Palembang, Indonesia⁴Universitas Negeri Makassar, Indonesia*Corresponding Address: haryantiputririzal@unsulbar.ac.id**Article Info**

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Energy as a socioscientific issue (SSI) demands the ability to think scientifically, argue rationally, and act ethically in complex real-world context. Future science teachers, particularly those from Generation Z, need to be equipped with these competencies to respond critically and responsibly to such challenges. This study aimed to analyze the quality of argumentation and decision-making among student groups in addressing energy-related socioscientific issues through collaborative discussion. A qualitative descriptive design with content analysis was employed, involving 15 student groups of second semester pre-service science teachers enrolled in matter and energy course across three different classes. Argumentation was analyzed using the Toulmin Argument Pattern (TAP), while decision-making was assessed through five aspects: criteria, evidence, perspectives, consequences, and justification. Each component was evaluated using a four-level rubric to determine the quality of students' responses. The findings revealed that both skills were at a moderate level, with mean scores of 1.93 for argumentation and 2.21 for decision-making. Students were generally able to formulate claims, however, they often lacked strong scientific justification and consideration of alternative viewpoints. Their decisions did not consistently reflect deep reasoning or align with the quality of their argumentation. These findings underscore the importance of integrating socioscientific issues-based instruction into science teacher education to strengthen scientific reasoning, ethical judgment, and evidence-based decision-making.

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INTRODUCTION

Energy is one of the most critical challenges both globally and nationally, requiring active engagement across sectors, including education. The transition from fossil fuels to renewable energy, unequal access to energy in remote areas, and the social and environmental impacts of energy policies make this issue multidimensional (Chang et al., 2020; Obrecht et al., 2020). In science education, energy issues fall under socioscientific issues (SSI), which are science-based yet socially debated problems involving ethical, cultural, and policy considerations

(Borgerding & Dagistan, 2018; Genisa et al., 2020). Thus, education plays a strategic role in enhancing energy literacy among younger generations to enable them to respond reflectively and responsibly (Pradana et al., 2019; Šedlbauer et al., 2024).

Generation Z, raised in the digital era, plays a pivotal role in facing the growing complexity of energy issues (Wijaya & Kokchang, 2023). As digital-native learners, they are accustomed to accessing information quickly through various platforms, including social media, which serves as a primary channel for the dissemination of issues related to science, the environment, and energy policy (Grzesiuk et al., 2023; Szymkowiak et al., 2021; Wijaya & Kokchang, 2023). Their open-mindedness, collaborative nature, and adaptability to technology represent significant potential for strengthening energy literacy and implementing SSI-based learning. This becomes increasingly relevant given that the majority of current pre-service science teachers belong to Generation Z, who will not only serve as facilitators of science education for the next generation but may also play a role in future policy-making. Therefore, it is essential to ensure that their educational process emphasizes not only conceptual understanding but also equips them with contextual competencies aligned with contemporary challenges (Gisewhite, 2023).

In line with their strategic role, pre-service science teachers must be equipped with essential skills to enable them to perform their roles actively and critically (Seibert, 2021). Two key competencies that are particularly crucial in this context are the ability to construct scientific arguments and to make evidence-based decisions (Forsythe & Chan, 2025). These competencies reflect an individual's capacity to comprehend scientific information, formulate logical reasoning, consider multiple perspectives, and evaluate the social implications of decisions made (Rizal et al., 2017, 2019). In the context of science education, these skills are not only vital for enhancing students' scientific literacy but also for shaping environmentally conscious and socially responsible citizens (Sengul, 2019; Turan et al., 2019).

Nevertheless, research indicates that pre-service teachers still face challenges in constructing well-structured arguments and making in-depth decisions regarding complex issues (Fasasi, 2017). Despite their broad access to information, students often lack the ability to critically and ethically filter that information (Ameen et al., 2023; Dalal et al., 2025). The culture of instant satisfaction, information overload, and the dominance of personal opinions in digital spaces further complicate the development of reflective and argumentative thinking (Dalal et al., 2025). Yet, pre-service science teachers bear an educational responsibility to communicate issues such as energy to their students. Without the ability to construct scientifically grounded arguments and make decisions that consider social and ethical dimensions, their effectiveness as educators will be significantly hindered (Heredia et al., 2024; Naquines et al., 2025).

Furthermore, the quality of argumentation and decision-making is closely linked to students' understanding of the scientific concepts underlying the issues being discussed (Cadena-Nogales et al., 2025; Rietz et al., 2021; Rizal et al., 2019). A solid understanding of relevant scientific concepts enables students to interpret information more accurately and construct arguments that are logically and scientifically grounded. Without a strong scientific foundation, students tend to produce weak arguments, rely on personal opinions, or make decisions that lack scientific justification (Rietz et al., 2021; Sparks et al., 2022). Conceptual understanding serves as the basis for objectively evaluating evidence and considering the social and ethical implications of various options.

Previous studies on socioscientific issues have predominantly focused on individual cognitive processes, particularly reasoning and conceptual understanding (Borgerding & Dagistan, 2018; Ladachart & Ladachart, 2021). However, there remains limited research examined how pre-service science teachers collaboratively construct arguments and make collective decisions in energy-related SSI contexts. This gap is particularly important because argumentative process also develop through group dynamics. Moreover, students in the digital

era tend to interact and make decisions collectively, often through digital forums and collaborative environments (Jafari & Meisert, 2021). Therefore, it is essential to evaluate how student groups construct and sustain arguments, as well as make collective decisions grounded in evidence and social values. To address this gap, the present study extends previous research by analyzing the quality of argumentation and decision-making through group-based discussions on energy-related socioscientific issues. Unlike most previous research that focused on individual reasoning, this study highlights collective argumentative processes and decision-making dynamics in classroom contexts.

In response to this gap, the objective of this study is to analyze the quality of argumentation and decision-making in responding to energy issues through group-based discussions. Specifically, this study examines how Generation Z pre-service science teachers develop arguments and make evidence-based decisions during group-based discussions on energy-related socioscientific issues. The study was conducted across three different classes to enrich the analytical context and capture a diverse range of students' thinking patterns. The findings are expected to contribute to strengthening the pedagogical and critical thinking competencies of future science educators and to provide a foundation for designing more contextual and responsive teaching models, curricula, and teacher education programs related to contemporary energy issues. More broadly, the results are also globally relevant, as energy education represents a cross-national challenge in shaping a generation of science educators who are critical, reflective, and committed to sustainability.

METHODS

This study utilized a qualitative descriptive approach using content analysis techniques to evaluate the quality of argumentation and decision-making among Generation Z pre-service science teachers. The data were collected and analyzed from students' written group discussion documents in the form of worksheets centered on energy-related issues, which were designed to elicit exploratory argumentation and decision-making. The research participants were second-semester students from the Science Education Program, specifically from Classes A, B, and C, aged between 19–20 years, who were enrolled in the “Matter and Energy” course. Students were divided into heterogeneous groups consisting of 4–5 members, with a total of 15 groups. Therefore, the unit of analysis in this study was the group rather than the individual in order to reflect the dynamics of collective thinking and collaborative reasoning. This grouping structure supports argumentation and decision-making processes that emerge through discussion and negotiation (Jafari & Meisert, 2021), distinguishing the present study from previous research that primarily analyzed these skills at the individual level.

Student argumentation was analyzed using a rubric based on the Toulmin Argument Pattern (TAP) which includes the elements of claim, data, warrant, backing, rebuttal, and qualifier. Responses containing only claims without supporting evidence were categorized at a lower level, whereas responses including claims, scientific evidence, justification and rebuttal were categorized at a higher level. Meanwhile, decision-making skills were analyzed using five components proposed by Qin (2025) includes Criteria, Evidence, Perspectives, Consequences, and Justification (Jimenez et al., 2023). Both rubrics were adapted from established theoretical frameworks, support the content validity instrument. Each component was scored using a four-point rubric ranging from low to high quality.

The data analysis procedure involved three stages including coding, categorization, and interpretation (Figure 1).

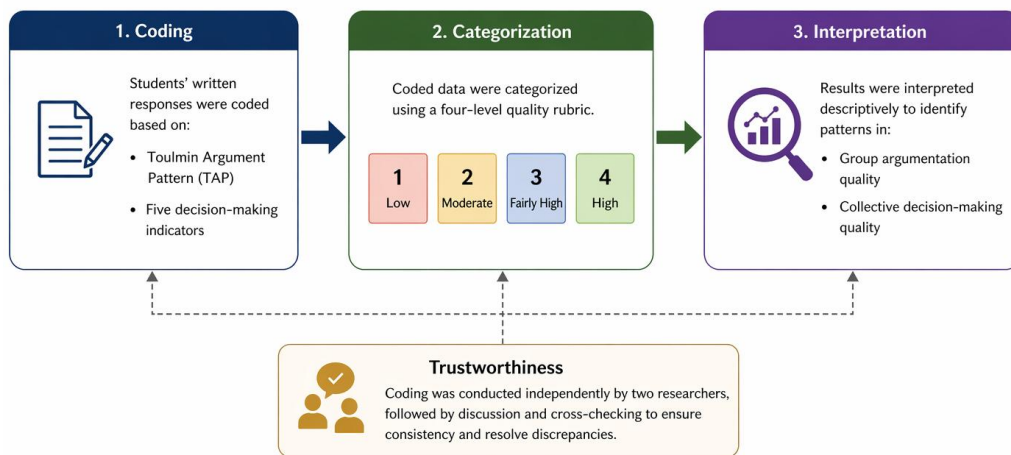


Figure 1. Analysis Procedure

First, students’ written responses were coded according to the TAP components and the five decision-making indicators. Second, the coded data were categorized based on the quality levels defined in the assessment rubric. Third, the findings were interpreted descriptively to identify patterns in the quality of group argumentation and collective decision-making across the three classes. To enhance the trustworthiness of the findings, coder discussions and cross-checking procedures were conducted to resolve discrepancies in coding and ensure consistency of interpretation. The final average scores were categorized into four levels (low, moderate, fairly high, and high). This classification approach was adapted from the categorical model developed by Dawson and Venville (2022).

RESULTS AND DISCUSSION

Argumentation Skill

This study reveals that the argumentation skills of Generation Z pre-service science teachers regarding energy issues fall within the moderate category, with an overall average score of 1.93. Although no group achieved the highest category, some groups demonstrated initial potential in constructing scientific arguments, particularly in basic structural elements such as claims. The highest-scoring group was Class A–Group 1 (2.33), while the lowest was Class B–Group 4 (1.67). The score distribution indicates that argumentation skills vary across groups, with most falling within the low to moderate categories. These findings suggest that, overall, Generation Z pre-service science teachers have not yet fully mastered the complete structure of scientific argumentation. The visualization in Figure 2 illustrates the average argumentation skill scores across the 15 student groups.

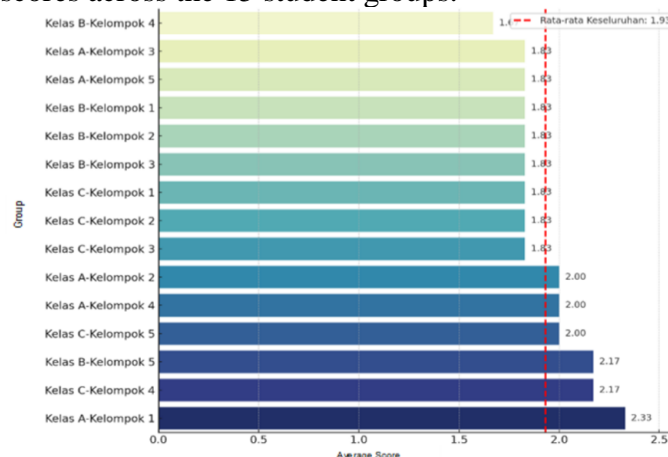


Figure 2. Average Argumentation Skills of Generation Z Pre-Service Science Teachers by Group

An analysis of each argumentation component namely Claim (stating a position), Data (supporting the claim with evidence), Warrant (explaining the logical connection between data and claim), Backing (support for the warrant), Qualifier (degree of certainty), and Rebuttal (reflection) reveals that students were particularly strong in stating claims (score: 3.60 – high category), but weak in supporting those claims with sufficient reasoning. These results are visualized in Figure 3.

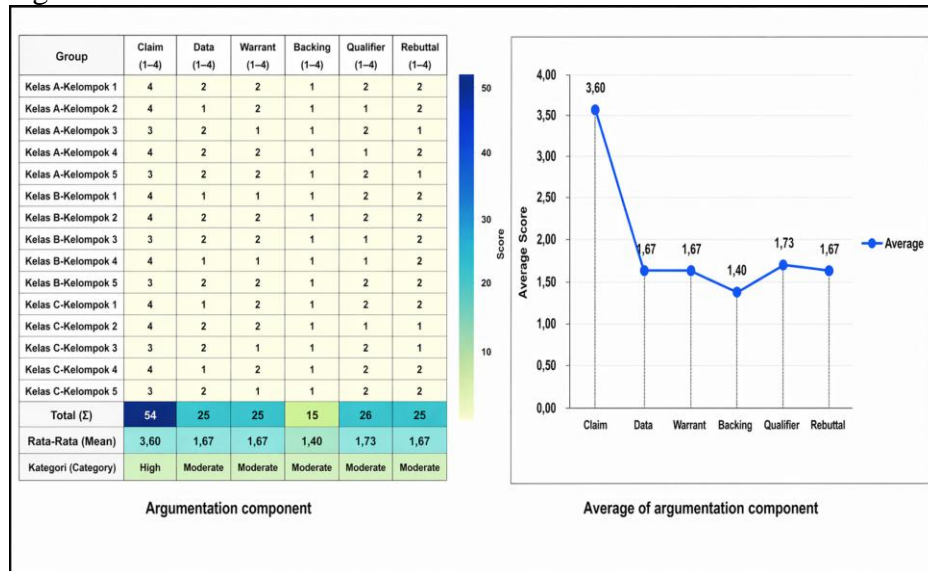


Figure 3. Average Argumentation Skills of Generation Z Pre-Service Science Teachers by Argumentation Component per Group

Components such as data, warrant, qualifier, and rebuttal all showed nearly identical average scores (1.67), while backing emerged as the weakest aspect, with the lowest average score (1.40). This indicates that while students were fairly confident in stating their positions on issues, they often failed to support those statements with strong evidence, scientific reasoning, or consideration of opposing viewpoints. For instance, a representative group response stated that “renewable energy should be prioritized because it is environmentally friendly and can reduce pollution in the long term.” This statement clearly reflects a claim, however it does not include supporting scientific evidence, such as data on emission reduction, energy efficiency, or economic feasibility. This pattern is also reflected in the low performance of the deeper argumentation components. Both the backing and rebuttal components reflect depth of thinking and reflective ability skills that were notably lacking in this study. Yet, these components are crucial within the context of socioscientific issues, as they enable students to revisit assumptions, consider alternative perspectives, and incorporate broader scientific judgments (Sengul, 2019; Widodo, 2023).

These findings reinforce previous research indicating that the basic structure of argumentation, such as making a claim is relatively easier to master (Novak & Treagust, 2018; Walker et al., 2019), whereas the more reflective and critical components (such as warrant, rebuttal, and backing) require explicit instruction and sustained practice (Dwi Angraini & Novika Pertiwi, 2024; Kuhn & Modrek, 2022; Lieber et al., 2022). In the context of Generation Z students, who have grown up with constant access to digital information and social media, the tendency to express opinions without deep reasoning is highly probable. Exposure to brief and instant information may foster surface-level thinking patterns rather than deeper, analytical thought processes (Dalal et al., 2025).

Pre-service science teachers will serve as facilitators of learning in schools. If they have not yet mastered the complete structure of scientific argumentation, it will be difficult for them to guide students in developing scientific thinking when addressing contemporary issues such as renewable energy, the impacts of energy policies, or inequalities in energy access. Therefore,

it is essential to design instructional interventions that focus on practicing the construction of complete argument structures based on the Toulmin model, while integrating Socio-Scientific Issues in a contextual and locally relevant manner (Cian, 2020; Khoiri et al., 2022; Sofiana & Arif, 2024), and provide feedback on the structure of arguments so that the quality of students' argumentation goes beyond merely stating opinions. Instead, arguments should be supported by evidence, logical justification, and an awareness of the social and ethical implications of each position taken (Esterhazy & Damşa, 2019).

Decision-Making Skill

This study also analyzed the decision-making abilities of Generation Z pre-service science teachers in the context of energy-related Socio-Scientific Issues. The analysis was conducted based on five aspects: Criteria, Evidence, Perspectives, Consequences, and Justification, with scores averaged for each group. Figure 4 presents the distribution of average decision-making scores across 15 groups from three different classes.

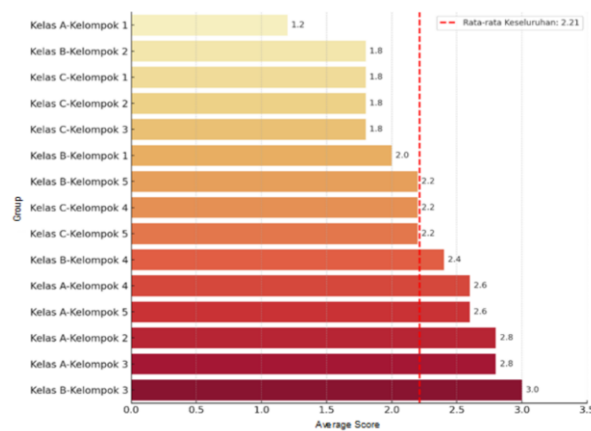


Figure 4. Average Decision-Making Skills of Generation Z Pre-Service Science Teachers

Based on the visualization in Figure 3, decision-making abilities in the context of energy-related SSI fall within the moderate category, with an overall average score of 2.21. The highest score was achieved by Class B–Group 3 (3.00), while the lowest was by Class A–Group 1 (1.20). Approximately 40% of the groups scored above the average, while the rest demonstrated relatively low performance. This variation reflects disparities in the ability to evaluate energy issues from a multidimensional perspective and to formulate balanced decisions that integrate scientific evidence, social values, and consequences. These findings indicate that most groups have yet to demonstrate optimal decision-making skills. Based on the analysis of five aspects includes Criteria, Evidence, Perspectives, Consequences, and Justification, the Criteria aspect received the highest score, indicating that students were able to establish an initial basis or rationale for deciding. The results are visualized in Figure 5.

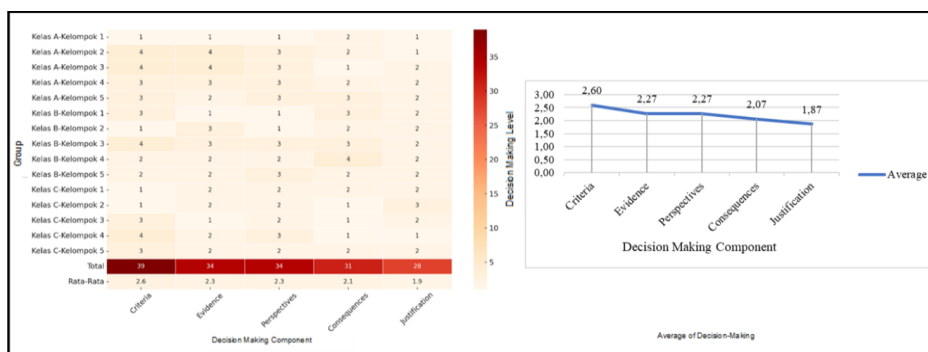


Figure 5. Average Decision-Making Skills of Pre-Service Science Teacher Student Groups by Decision-Making Aspect

Aspects that require deeper analysis and ethical reflection such as Consequences and especially Justification remain relatively low. This indicates that students have not yet fully developed the ability to integrate scientific evidence, consider alternative perspectives, and evaluate social and ethical impacts comprehensively in the decision-making process. These findings are consistent with previous studies suggesting that decision-making in the context of SSI is not solely dependent on cognitive factors, but also involves social-affective and moral dimensions (Alred & Dauer, 2020; van der Leij et al., 2023). Therefore, the quality of a good decision lies not only in what is chosen, but also in how and why the decision is made.

A particularly noteworthy and novel finding of this study is the mismatch between the quality of argumentation and the quality of decision-making. For instance, Class A–Group 1 recorded the highest argumentation score but had the lowest decision-making score, whereas some groups in Class B demonstrated relatively strong decision-making despite weaker argumentation. This finding indicates that argumentative ability does not always align linearly with decision quality. In SSI contexts, final decisions may also be shaped by personal values, group dynamics, consensus-building processes, and social considerations (Vicente et al., 2024), particularly when the discussion process is not inclusive or reflective. In relation to Gen Z characteristics, these results align with their tendency to rapidly absorb information, while also be susceptible to instant gratification culture and digital social pressures (Ameen et al., 2023), which may lead to decision-making patterns that are more intuitive than analytical (Genisa et al., 2021). Additionally, considering that the students are aged around 19–20, they are still in the development phase of higher-order thinking skills. With the appropriate pedagogical approaches, this stage presents a valuable opportunity to strengthen their reasoning and decision-making capacities (Chardonnens, 2025).

In response to the identified mismatch between argumentation quality and decision-making performance, the implementation of contextual SSI-based pedagogical interventions is highly recommended. For instance, employing instructional strategies such as energy debate simulations, case analyses of local coal-fired power plants, or the use of infographics and real-time data on energy consumption can enhance student engagement and promote deeper thinking (Kimsron et al., 2025; Kruit et al., 2025; Owens & Sadler, 2024). Integrating exploratory projects like an Energy Decision-Making Journal can further support both personal and collaborative reflection on energy choices and their impacts. In addition, explicit instruction on the structure of scientific arguments, accompanied by scaffolded feedback, can help strengthen weaker components such as warrant, backing, and rebuttal (Yang et al., 2022). These targeted interventions not only support conceptual understanding but also foster the development of critical, ethical, and evidence-based reasoning skills essential for pre-service science teachers in preparing future generations to navigate complex socioscientific challenges (Zidny et al., 2021).

CONCLUSION

This study reveals that Generation Z pre-service science teachers still require further support in developing of argumentation and decision-making skills in the context of energy-related socioscientific issues. In general, they are able to construct claims, but deeper component such as evidence-based justification, consideration of consequences, and ethical-social reflection remains less developed. Theoretically, this study contributes by integrating the TAP with a decision-making framework to provide more comprehensive understanding of how pre-service science teachers reason through SSI. These findings underscore the importance of SSI-based learning that systematically develops critical, argumentative and reflective thinking skills. Classroom strategies such as structured debates, local energy case analysis, collaborative argument mapping, and reflective decision-making journals are recommended to strengthen both reasoning and decision quality. Future research is encouraged to explore the relationship between the quality of argumentation and decision-making through correlational or

experimental approaches to support the development of effective and contextual SSI-based curricula

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