

Exploring Gender Differences in Students' Perceptions of STEM Careers, Systems Thinking Skills, and Environmental Literacy

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Article Info	Abstract
Article history: Received: March 8, 2026 Accepted: April 28, 2026 Published: May 1, 2026 Keywords: Chemistry learning Environmental literacy Gender STEM Systems thinking skills This article is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License. © 2026 Vidya Karya	STEM-based learning plays an important role in preparing students to face the challenges of the 21st century, particularly in developing systems thinking skills, environmental literacy, and career orientation in science and technology fields. Indonesia's performance in international assessments such as PISA and TIMSS, which remains below the global average, indicates the need to strengthen STEM education in schools. This study aims to analyze high school students' perceptions of STEM careers, systems thinking abilities, and environmental literacy in the context of chemistry learning. A quantitative descriptive method was used in this research, involving 101 high school students, consisting of 28 males and 73 females. Data were analyzed using descriptive statistics in the form of frequencies and percentages. Overall findings indicate that students have positive perceptions of the three variables studied. However, the ability to formulate solutions to complex chemistry problems and confidence in solving environmental issues still need improvement. For future research, it is recommended to develop more contextual STEM-based learning models to further strengthen students' systems thinking skills and environmental literacy.
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INTRODUCTION

The 21st century is characterized by the rapid development of science, technology, engineering, and mathematics (STEM), which has significantly influenced quality of life and brought about changes in various aspects of human existence (Nugroho et al., 2019). This situation encourages students to develop active, creative, and innovative attitudes, as well as master 21st-century skills known as the 4Cs (critical thinking, creativity, collaboration, and communication) in facing various learning challenges (Rosmini et al., 2025). In response to the rapid advancement of knowledge, STEM-based education has emerged to integrate real-life contexts (Sumartati, 2020) so that students are equipped not only with basic skills but also with the 4C competencies that are highly needed in this era (Novitasari et al., 2023). More than just a learning approach, STEM encompasses scientific fields that study the processes and mechanisms of nature with the aim of improving the quality of human life (Hasiani et al., 2020). The importance of STEM is also reflected in international assessments such as the Programme for International Student Assessment

(PISA) and the Trends in International Mathematics and Science Study (TIMSS), where Indonesia's achievement remains below the global average, making the strengthening of STEM learning crucial for improving students' problem-solving abilities. This is evidenced by the increasing demand for labor in the era of Industry 4.0, particularly in information technology and engineering fields, ranging from application programmers and data analysts to technicians in the mechanical, electrical, and chemical sectors ([Haryani, 2024; Latifah et al., 2024](#)). However, in reality, students' interest in these fields remains relatively low, as science and mathematics are often perceived as difficult and less attractive ([Putri et al., 2025; Siregar et al., 2023](#)), a perception supported by a curriculum that does not sufficiently explore science and engineering in depth and by students' limited access to information regarding career opportunities in these areas ([Hiğde & Aktamış, 2022](#)).

Students' career interests are influenced by many factors. Within the framework of Social Cognitive Career Theory (SCCT), career choices are shaped through the interaction of internal, environmental, and socio-cultural factors ([Bagaskara & Sulistiobudi, 2023](#)), including abilities, interests, achievements ([Nasution, 2019](#)), and self-confidence ([Komara, 2016](#)). Perceptions regarding differences in abilities between individuals can indirectly affect the support provided by parents and teachers in guiding students' career choices in STEM fields. In Indonesia, research related to STEM education has developed and revealed various findings regarding the increase of students' interest and competence in science and technology ([Yatin & Abidin, 2020](#)). However, most of these studies still focus on specific aspects separately, such as interest in STEM careers or systems thinking skills. Therefore, there remains a research gap in examining the integrated relationship between STEM career perceptions, systems thinking skills, and environmental literacy, particularly from a gender perspective. Thus, strengthening secondary students' interest in science and engineering continues to be important to support national progress ([Marlina et al., 2021](#)). In addition to career interest, systems thinking skills are an essential competency in STEM career development. These skills enable students to understand the interconnections among components within a complex system and to analyze problems comprehensively ([Shidiq et al., 2020b, 2021, 2022b, 2024](#)). In the context of the STEM workforce, systems thinking is highly needed to address real-world problems that are complex, multidisciplinary, and require integrated as well as innovative decision-making ([Misriani et al., 2023a; Mahaffy et al., 2019; Orgill et al., 2019](#)). Thus, these skills not only support conceptual understanding but also play a role in enhancing students' readiness to meet the demands of careers in science and technology.

Furthermore, systems thinking skills are also closely related to environmental literacy, which is one of the key competencies in STEM fields, especially those concerning sustainability issues. Environmental literacy encompasses not only conceptual understanding but also the ability to analyze, evaluate, and respond appropriately to environmental problems ([Farwati et al., 2017](#)). In this context, systems thinking helps students grasp the complexity of environmental issues involving various aspects such as ecology, society, and economics. Therefore, the development of environmental literacy should be supported by systems thinking skills so that students are able to formulate more comprehensive and sustainable solutions. This aligns with sustainability-based learning, which emphasizes the importance of integrating knowledge, skills, and attitudes in addressing global environmental challenges ([Wilujeng et al., 2019; Setiawan et al., 2025a](#)).

The STEM approach has been recognized as effective in fostering problem-solving abilities and innovation in addressing environmental issues. Nevertheless, solving complex sustainability challenges requires not only mastery of scientific disciplines but also systems thinking skills that enable students to understand the dynamic relationships within socio-ecological systems ([Blatti et al., 2019](#)). Moreover, students' perceptions of STEM careers play a crucial role in shaping motivation, participation, and long-term engagement in this field. In this context, examining gender perspectives is essential, as various studies have

shown that males and females experience STEM learning and career development differently. These differences are related not only to interest but are also influenced by sociocultural factors such as gender stereotypes, social expectations, self-efficacy, and access to learning and career development opportunities [Kartimi et al., 2021](#); [Shidiq et al., 2020a, 2022b](#); [Yamtinah et al., 2017a](#)). Such conditions may affect students' readiness to develop the competencies needed to face future sustainability challenges.

Although studies related to STEM career perception, systems thinking skills, and environmental literacy continue to develop, most studies still examine these three aspects separately or are limited to specific combinations. Research that integrates these three variables in a single analytical framework, especially considering gender perspectives, is still relatively limited. This gap is increasingly visible in the context of developing countries, including Indonesia, where research related to STEM and sustainability still tends not to accommodate multidimensional approaches. Therefore, this study aims to fill these gaps by simultaneously analyzing students' perceptions of STEM careers, systems thinking skills, and environmental literacy based on gender differences. The novelty of this research lies in an integrative approach that connects cognitive and affective dimensions in environmental education and places them in the context of career development and gender equality in STEM fields. Based on this description, this study aims to analyze students' perceptions of careers in the STEM field and examine students' system thinking skills and environmental literacy.

METHODS

This study employed a quantitative descriptive survey design to analyze gender differences in students' perceptions of STEM careers, as well as to assess students' systems thinking skills and environmental literacy. This design was selected because it enables the collection of data from a defined population to describe existing conditions without manipulating research variables [\(Yamtinah et al., 2017b, 2023\)](#).

The population of this study consisted of all eleventh-grade students at one of the high schools in Surakarta. The sample was drawn from five science classes (F1–F5) that had participated in STEM-based learning. Participants were selected using random sampling, with inclusion criteria limited to students who were willing and actively participated in completing the research instrument. A total of 101 students were involved as respondents in this study. The questionnaire was distributed online, allowing all students to freely participate in the survey. Participation was voluntary, and all respondents who completed the questionnaire were considered to have provided their consent to be involved in the study.

Data were collected using a structured questionnaire developed by the researchers. The instrument measured three main variables: (1) students' perceptions of STEM careers, (2) systems thinking skills, and (3) environmental literacy. All items were assessed using a four-point Likert scale, ranging from 1 (strongly agree) to 4 (strongly disagree). The questionnaire items were adapted from previous studies and adjusted to align with the objectives of this research [\(Anderson & Cooper, 2022; Kier et al., 2014; Playton et al., 2024; Szczytko et al., 2019\)](#). The validated indicators for each variable are presented in Table 1.

Table 1 Research indicators

Aspect	Indicators	Question numbers
STEM Careers	Self-Efficacy in STEM Abilities	1, 2, 11
	Environmental Support for STEM Careers	4, 5, 6, 7
	Interest and Orientation Toward STEM Careers	3, 8, 9, 10
Systems thinking	Core	1, 2, 3, 4, 5
	Advanced	6, 7, 8, 9, 10
Environmental literacy	Core	1, 5, 8, 9
	Advanced	2, 3, 4, 6, 7, 10

Data collection was conducted through an online survey distributed to the selected participants. Before completing the questionnaire, students were informed about the purpose of the study and provided their consent to participate. Only responses that were fully completed were included in the analysis.

The collected data were exported and analyzed using descriptive statistical methods, including frequency and percentage. This analysis aimed to identify patterns and trends in students' responses regarding STEM career perceptions, systems thinking skills, and environmental literacy. The study did not aim to examine causal relationships but rather to provide a comprehensive description of students' characteristics related to the variables studied. The findings are expected to offer insights into students' readiness to face future challenges in science, technology, and environmental contexts. The research procedure flow is shown in Figure 1.

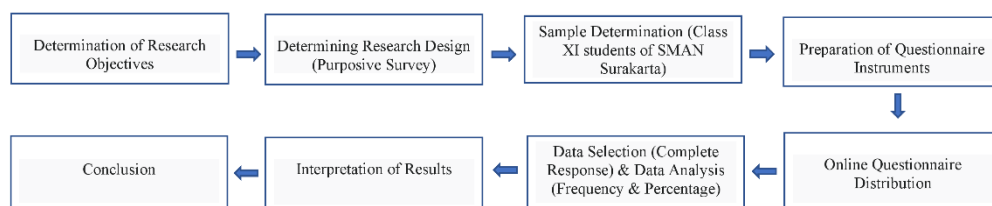


Figure 1 Flow of research procedure

RESULTS AND DISCUSSION

Data analysis was conducted to see students' perceptions of careers in the STEM field, as well as systems thinking skills and environmental literacy, using a questionnaire instrument with a four-level Likert scale, namely strongly agree (1), agree (2), disagree (3), and strongly disagree (4). The analysis was carried out based on the indicators that have been set for each research variable.

STEM Careers

The indicators used are based on [Kier et al., \(2014\)](#); [Playton et al., \(2024\)](#) which discuss the development and validation of instruments for measuring students' interest and awareness regarding STEM learning and careers at various educational levels. The researcher adapted 11 questions, which are divided into three perceptions of STEM careers: self-efficacy in STEM abilities, environmental support for STEM careers, and interest and orientation toward STEM careers. The respondents in this study consisted of 101 students, comprising 28 male students (27.72%) and 73 female students (72.28%). The results of the comparative analysis of students' perceptions based on gender are presented in the following Table 1.

Table 2 Self-efficacy in STEM abilities

No	Statement	Strongly Agree & Agree	Percentage
1.	Able to achieve good grades in STEM subjects.		
	Male (L)	23	82.14%
	Female (P)	60	82.19%
2.	Able to perform daily tasks that involve STEM.		
	Male (L)	25	89.28%
	Female (P)	65	89.04%
11.	Feels comfortable communicating with professionals in STEM career fields		
	Male (L)	25	89.28%
	Female (P)	64	87.67%

[Nasution \(2019\)](#) states that ability is self-confidence related to outstanding talent in a cognitive field, skill field, or artistic field. The results in Table 2 show that students' confidence in STEM abilities is relatively high, which can be seen from the dominance of positive responses in all indicators. The percentage between male and female students is also relatively balanced, so it does not show significant differences by gender. The high percentage of indicators of ability to achieve grades and carry out daily activities related to STEM shows that students not only feel able to understand the material but also are quite confident in applying it in real life. In addition, the high level of comfort of students in communicating with professionals in the STEM field indicates that there is early readiness to face the future career environment. However, these findings need to be examined further because high self-confidence does not necessarily fully reflect a student's actual abilities. This shows that there is still a need to strengthen learning that not only increases confidence, but also ensures the mastery of relevant skills so that students' readiness in the STEM field becomes more optimal. Statements related to the influence of family or environment on STEM can be seen in Table 3.

Table 3 Environmental support for STEM careers

No	Statement	Strongly Agree & Agree	Percentage
4.	Family encourages the use of STEM skills in adulthood.		
	Male (L)	27	96.42%
	Female (P)	64	87.67%
5.	Knows individuals who utilize STEM skills in their work.		
	Male (L)	24	85.71%
	Female (P)	63	86.30%
6.	Knows family members who use STEM in their careers		
	Male (L)	22	78.57%
	Female (P)	48	65.75%
7.	Interested in careers that utilize STEM		
	Male (L)	21	75%
	Female (P)	53	72.60%

The results in Table 3 show that environmental support, especially from families and individuals around students, plays a role in shaping STEM career orientation. The percentage of positive responses to the family support indicator is very high, especially for male students (96.42%) compared to female students (87.67%). This shows that families are an important factor in encouraging students to utilize STEM skills in the future. Parental support for STEM can influence children's interest in STEM careers. Previous studies also state that parents' attitudes and values toward STEM can shape their children's attitudes and values toward STEM ([Bagaskara & Sulistiobudi 2023](#)). In addition, most students also claim to know individuals who work in STEM fields, with a relatively balanced percentage of men and women. These findings indicate that exposure to STEM professions in the surrounding environment is good enough and has the potential to be a source of inspiration for students. However, in the indicator of family members' involvement in STEM careers, the percentage obtained was lower, especially in female students (65.75%). This shows that not all students have direct role models within the family scope, which can affect the formation of their career aspirations. In the indicator of interest in STEM careers, the percentage of positive responses is still relatively high, but lower than the environmental support indicator. This condition indicates that environmental support and exposure are not fully proportional to students' level of interest in STEM careers. Overall, these findings confirm that the social environment has an important role in shaping perceptions of STEM careers, but its influence is not fully optimal in driving students' interest directly. This is in line with previous research that states that environmental support needs to be balanced with meaningful learning experiences in order to effectively increase interest and career

readiness in STEM fields. Interest and orientation towards careers in STEM are listed in Table 4.

Table 4 Interest and orientation toward STEM careers

No	Statement	Strongly Agree & Agree	Percent
3.	STEM will be beneficial as I grow up		
	Male (L)	28	100%
	Female (P)	70	95.89%
8.	Enjoys STEM-related classes.		
	Male (L)	24	85.71%
	Female (P)	59	80.82%
9.	Plans to use STEM in future careers.		
	Male (L)	27	96.42%
	Female (P)	65	89.04%
10.	Will study diligently in STEM classes.		
	Male (L)	25	89.28%
	Female (P)	68	93.15%

The results in Table 4 show that students' interest and orientation towards STEM careers are relatively high. This can be seen from the dominance of positive responses in all indicators, especially in the perception of future STEM benefits, which almost reach all respondents. These findings indicate that students have a very positive view of the relevance of STEM in their lives and careers. In addition, most students also show interest in STEM learning, which is reflected in the high percentage of preference indicators for STEM-related classes. This shows that the learning experience gained by students is quite capable of attracting their interest in the field. Furthermore, the high percentage of indicators of plans to use STEM in future careers indicates a tendency for students to associate the learning they have obtained with the career choices to be taken. Interestingly, in the indicators of learning commitment, female students showed a slightly higher percentage than male students. This indicates that although there is a higher tendency for male students to have higher self-confidence in other aspects, female students have a strong motivation to learn in STEM fields. Overall, these findings suggest that students not only have an interest in STEM, but are also starting to lead to the formation of career orientations in the field. However, when associated with the findings in the previous aspect, this high interest has not been fully offset by optimal environmental confidence and support. This is in line with previous research that stated that career interests need to be supported by internal and external factors in order to develop into real career choices. Quirkos is generated from the 4 statements listed in Figure 2.

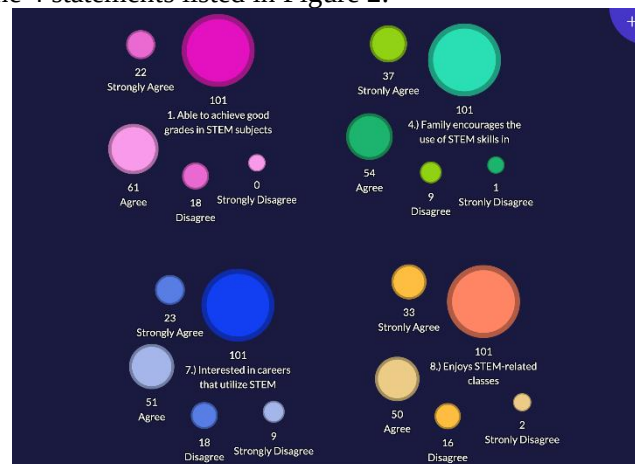


Figure 2 Quirkos results from 4 statements

From the statements above, Figure 1 shows students' answers to 4 statements. Based on the analysis of the three aspects above, self-efficacy in STEM abilities, environmental support, and interest and orientation toward STEM careers, most students demonstrate positive perceptions regarding the importance of STEM for their learning and future. The high percentage of “agree” and “strongly agree” responses indicates that students recognize the benefits of STEM and its relevance to their lives and future careers. This pattern suggests that students' positive perceptions are not merely the result of classroom experiences but are also closely related to the broader process of career development. Career development is a dynamic and continuous process that occurs across different stages of life and plays a crucial role in shaping career planning. It is influenced by self-understanding, values, attitudes, perspectives, individual abilities, and expectations, as well as by the interaction between internal factors and external environmental influences ([Nasution \(2019\)](#)). Therefore, the alignment between students' self-efficacy, environmental exposure, and career orientation in this study reflects an ongoing developmental process rather than a static condition.

When viewed by gender, male students tend to show slightly higher percentages on most indicators. These findings are in line with the results of the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS), which emphasize the importance of science and mathematics skills in education. However, men's self-efficacy is not always in line with cognitive achievement, as some reports show that the difference in achievement between men and women is relatively small or balanced. This indicates a gap between the perception of ability and actual ability. These findings are also supported by research showing that male students tend to have higher levels of self-confidence than female students in [Fointuna \(2025\)](#). On the other hand, female students show a higher percentage on certain indicators, such as study perseverance and connectedness to STEM environments. Thus, career orientation in the STEM field is not only determined by self-confidence but also influenced by other factors such as learning motivation, social exposure, and quality of interaction with the environment ([Yamtinah et al., 2017b, 2023](#)).

Systems thinking

Based on the indicators from [Anderson & Cooper \(2022\)](#); [Assaraf & Orion \(2010\)](#) within the EOP Framework, the 10 selected statements can be grouped into two competency levels: core (basic systems thinking skills) and advanced (advanced systems thinking skills) to measure systems thinking in one of the STEM subjects, namely chemistry. The indicators for core-level systems thinking skills can be seen in Table 5, while the indicators for the advanced level are presented in the following table.

Table 5 Students' perceptions of core level system thinking ability

No	Statement	Strongly Agree & Agree	Percentage
1.	Able to see the relationships between parts of a chemical system.	81	80.19%
2.	Realizes that chemistry, such as reactions consisting of various substances that interact dynamically, can affect the entire system.	92	91.08%
3.	Considers how changes in a chemical system can affect other components and the system as a whole.	88	87.12%
4.	Knows that the use of chemicals should consider the situation.	98	97.02%
5.	Feels able to find solutions to complex chemical problems.	56	55.44%

As shown in Table 5, the analysis indicates that students' system thinking ability at the core level is relatively good. This is reflected in the high percentage of positive responses across most indicators, particularly in students' understanding that chemical systems are dynamic and interdependent, as well as the importance of considering the use of chemicals according to specific conditions. These findings indicate that students have been able to understand the basic concept of the interconnectedness between components in a system. However, there is a fairly striking difference in the indicator of ability to find solutions to complex chemical problems, which shows the lowest percentage compared to other indicators. This indicates that even though students are able to recognize relationships in a system, they still have difficulty applying that understanding to solve more complex problems. This condition shows that students' systems thinking skills are still at the basic stage, which is limited to understanding the relationships between components, but have not developed optimally at the analysis and problem-solving stage. These findings are in line with previous research indicating that science learning in schools still tends to focus on mastering concepts and routine problems, thus providing limited opportunities for students to develop systems thinking skills in depth ([Shidiq et al., 2024](#); [Schuler et al., 2018](#); [Orgill et al., 2019](#)). Overall, these results confirm that although students' basic understanding of chemical systems is good enough, efforts are still needed to improve systems thinking skills at a higher level, especially in the context of complex and contextual problem-solving. Students' perceptions of advanced systems thinking skills are shown in Table 6.

Table 6 Students' perceptions of advanced-level systems thinking skills

No	Statement	Strongly Agree & Agree	Percentage
6.	Understands that small changes can impact the chemical system.	94	93.06%
7.	Recognizes the importance of identifying and mapping data patterns from chemical experiments before drawing accurate conclusions.	92	91.08%
8.	Considers the long-term effects of a choice.	93	92.07%
9.	Thinks about chemical solutions from various perspectives.	84	83.16%
10.	Traces the main causes of problems in chemical experiments before determining solution steps.	85	84.15%

As presented in Table 6, the analysis of the five advanced-level systems thinking statements indicates that students' advanced systems thinking ability is relatively high, as reflected by the dominance of positive responses across all indicators. Students are generally able to understand that chemical systems are dynamic, recognize data patterns from experimental results, and consider the long-term impact of an action. These findings indicate that some students have reached a more complex stage of systems thinking, not only in the understanding of relationships but also in the aspects of analysis and evaluation. In addition, students' ability to consider various perspectives and trace the root causes of a problem also shows that they are beginning to develop a more reflective and in-depth mindset. This is an important indicator of high-level thinking skills, especially in the context of scientific problem-solving. However, when compared to the results at the core level, these findings show inconsistencies, wherein certain indicators at the basic level, students still have difficulty in solving complex problems. This condition indicates that although students have a high perception of advanced systems thinking skills, these skills have not been fully applied consistently in practice.

Collectively, the results of this study demonstrate that students are not only able to recognize relationships between components within a system but are also beginning to develop more analytical systems thinking skills. This ability is crucial in science and

technology, as it facilitates an understanding of complex and interconnected problems. This finding is consistent with the argument by [Haniyah & Hamdu \(2022\)](#) that real-world problems require systems thinking skills, and is further supported by studies from [Schuler et al. \(2018\)](#); [Shidiq et al. \(2022a\)](#), which state that systems thinking helps in understanding dynamic systems and supports problem-solving in learning.

Environmental literacy

The environmental literacy instrument in this study was adapted from the indicators proposed by [Szcztyko et al. \(2019\)](#), which include four main aspects: hope, behavior, cognitive skill, and ecological knowledge. Within the EOP Framework, environmental literacy is classified into two competency levels: core (Basic Environmental Literacy Skills) and advanced (Advanced Environmental Literacy Skills). Students' perceptions of core-level environmental literacy skills are shown in Table 7.

Table 7 Students' perceptions of core-level environmental literacy skills

No	Statement	Strongly Agree & Agree	Percentage
1.	Assessing the quality of education is important to address environmental problems and build resilient, sustainable individuals.	100	99%
5.	Feeling unable to solve very complex environmental problems.	39	38.61%
8.	Throwing away garbage found in public places	93	92.07%
9.	Treating waste before it is disposed of in nature can reduce the impact of environmental problems.	99	97.02%

As shown in Table 7, the analysis indicates that students' environmental literacy at the core level is relatively good, as reflected in the high percentage of positive responses across most indicators. The analysis shows that students' environmental literacy at the core level is relatively good, which is characterized by a high positive response to most indicators. Students demonstrate a strong understanding of the importance of education in addressing environmental problems as well as awareness of waste management efforts as part of solutions. In addition, environmentally caring behaviors, such as throwing garbage in place, also look quite good, which shows a link between knowledge and action. Nevertheless, on indicators related to confidence in solving complex environmental problems, the percentage of positive responses tended to be lower. This indicates that even though students have good knowledge and awareness, they still lack confidence in dealing with complex environmental problems. These findings show that students' environmental literacy is still dominated by aspects of basic knowledge and behavior, but has not fully developed in the aspect of problem-solving skills. This is in line with previous research that states that the development of environmental literacy not only requires conceptual understanding but also needs to be supported by critical thinking skills and experience in solving real-world problems ([Szcztyko et al., 2019](#); [Wilujeng et al., 2019](#); [Setiawan et al., 2025a](#)). Students' perceptions of advanced environmental literacy skills are shown in Table 8.

The results in Table 8 show that students' environmental literacy at the advanced level is relatively high, which is characterized by the dominance of positive responses in all indicators. Students not only understand the importance of environmental conservation and sustainability but also realize that such responsibility is a shared role between individuals and communities. This shows that there are developments in the more complex cognitive aspects in understanding environmental issues. In addition, students also show awareness of concrete actions that can be taken to reduce environmental impacts, such as the use of public transportation, recycling, and energy saving.

Table 8 Students' perceptions of advanced-level environmental literacy skills

No	Statement	Strongly Agree & Agree	Percentage
2.	Supporting the use of nature conservation areas while maintaining ecosystem sustainability as biotic capital.	100	99%
3.	Recognizing that conserving biological resources and ecosystems is a shared responsibility between the government and the community.	100	99%
4.	Being aware that various efforts, such as using public transportation, can help reduce environmental problems.	93	92.07%
6.	Recycling waste to reduce environmental problems.	85	84.15%
7.	Turning off lights at home when not in use.	93	92.07%
10.	Realizing that appropriate land use on slopes is an effort to prevent erosion.	97	96.03%

These findings indicate that students' environmental literacy is not only at a conceptual level but also begins to be reflected in daily behavior. However, when it comes to outcomes at the core level, there is still an imbalance between understanding and belief in solving complex environmental problems. This shows that even though students have good awareness and behavior, the ability to manage and solve environmental problems in depth still needs to be improved. Overall, these findings confirm that students' environmental literacy has developed to the aspects of knowledge and behavior but still requires strengthening of high-level thinking and problem-solving skills. This is in line with previous research that states that comprehensive environmental literacy includes not only awareness and action but also the ability to analyze and make appropriate decisions in dealing with environmental issues.

Taken together, the results of this study indicate that students possess a fairly good level of environmental literacy, both at the core and advanced levels, as reflected in their understanding, awareness, and pro-environmental behavior in daily life. These findings carry important implications for curriculum development and teaching practice, suggesting that integrating environmental issues into STEM-based learning can simultaneously strengthen conceptual understanding and foster responsible environmental behavior, thereby preparing students to address global challenges through science and technology fields ([Kaya & Bulut, 2022](#)). Across all three variables, students demonstrated positive perceptions, with strong self-efficacy, social support, and career interest in STEM, as well as emerging systems thinking abilities, though the capacity to formulate solutions to complex problems remains an area for development. Notably, male students exhibited slightly higher self-confidence than female students, a gap that may reflect sociocultural influences or unequal classroom experiences, highlighting the need for more inclusive learning environments that actively support female students' self-efficacy and ensure equal access to STEM career pathways. Furthermore, strengthening students' awareness and sense of responsibility toward the environment remains a crucial part of fostering sustainable behavior ([Setiawan et al., 2025b](#)). Nevertheless, this study has limitations, as the use of a single-school sample restricts the generalizability of the findings, and the descriptive design does not permit causal conclusions, suggesting that future research employs larger, more diverse samples and experimental designs. Taken together, the results of this study indicate that students possess a fairly good level of environmental literacy, both at the core and advanced levels. This is evident from the high levels of understanding, awareness, and environmentally responsible behavior demonstrated by students. These findings show that students not only understand environmental concepts but have also begun to apply them in their daily lives. This is important, as the development of environmental literacy can support efforts to address various global challenges through

science and technology fields ([Kaya & Bulut, 2022](#)). Furthermore, strengthening students' awareness and sense of responsibility toward the environment is also a crucial part of fostering sustainable behavior ([Setiawan et al., 2025b](#)).

CONCLUSION

This study shows that students have positive perceptions of all three variables examined. In terms of STEM career perceptions, most students have high self-efficacy in STEM abilities, receive support from their social environment, and demonstrate strong interest and career orientation in the field, although male students tend to have slightly higher self-confidence compared to female students. Regarding systems thinking skills, students are able to recognize relationships among components in chemical systems and are beginning to develop more complex analytical abilities, although the ability to formulate solutions to complex problems still needs improvement. For environmental literacy, students not only possess good conceptual understanding but also demonstrate awareness and behaviors that support environmental sustainability in their daily lives. Taken together, these findings indicate that strengthening STEM-based learning has the potential to foster better systems thinking skills and environmental literacy among students. Based on these findings, several directions for future research are recommended. First, future studies should employ experimental or quasi-experimental designs to establish causal relationships between STEM-based learning interventions and improvements in systems thinking and environmental literacy. Second, expanding the sample to include multiple schools across diverse geographic and socioeconomic contexts would enhance the generalizability of the findings. Third, longitudinal studies are needed to examine how students' STEM career perceptions, systems thinking skills, and environmental literacy develop over time. Finally, future research should further explore gender differences in STEM self-efficacy by investigating the underlying sociocultural factors, with the aim of developing more equitable and inclusive learning strategies.

CONFLICTS OF INTEREST

The authors state that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

The corresponding author (ASS) initiated the research idea, designed the study, secured funding, supervised the overall research process, and provided academic direction. The first author (IO) was responsible for the implementation of the research, including data collection, data analysis, and preparation of the initial draft of the manuscript. The third and fourth authors (SY and PAWP) contributed to data interpretation, manuscript review, and ensuring the consistency and overall quality of the final manuscript. All authors have reviewed and approved the final version of this article.

AI DISCLOSURE STATEMENT

The authors used Grammarly Translator during the process of drafting this work to help translate the manuscript. After using the tool, the authors conducted a thorough review and editing to ensure the quality and accuracy of the content. The authors are solely responsible for all published content. In addition, the authors stated that the research, writing, and editing process was carried out without the involvement of artificial intelligence (AI) techniques.

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