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High School Students' Argumentation Skills: Biology Learning Innovations with the STEM-RANDAI Model

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ABSTRACT

Objective: Develop students' argument skills through biology learning based on the STEM-RANDAI model. This model integrates six phases (reciting, analyzing, narrating, doing the solution, assessing, and implementing), so that students not only learn science concepts, but also build evidence-based arguments through collaborative and contextual activities. **Method:** This study adopted a quasi-experimental design with a Nonequivalent Control Group Design involving three groups (experimental class, positive control class and negative control class) to compare the results (posttest) between the three groups after the treatment was given. The goal is to apply the STEM-RANDAI model and develop innovative biology learning tools to improve students' argument skills. **Results:** The findings of the study show that there is a significant influence of the STEM-RANDAI learning model on the improvement of argumentation skills with a significance value of $p = 0.000$ ($p < 0.001$). **Novelty:** The novelty of this research lies in the RANDAI (Culture-based learning) model integrated with the STEM approach (STEM-RANDAI model) which is explicitly adapted to the context of West Sumatra high schools, Indonesia. The integration of cultural values in this learning model makes model innovation that is relevant to the needs of the 21st century, as well as unique by combining the two to create a model that addresses the gap in argument skills of students in West Sumatra, Indonesia.

INTRODUCTION

In the 21st century, argumentation skills are essential for science learning. Argumentation enables students to construct claims, evaluate evidence, justify reasoning, and engage in scientific discourse, all essential components of scientific literacy and second-century skills (Dawson, 2024). Argumentation skills are defined as the capacity of individuals to express opinions supported by relevant facts and evidence (Hardini & Alberida, 2022). Arguing is a practice that combines various viewpoints, both socially and scientifically, that is often a cause of controversy outside of the science classroom environment (Garrecht et al., 2021). International educational frameworks such as PISA and the Next Generation Science Standards (NGSS) highlight argumentation as a crucial practice in science learning. Therefore, effective science learning must facilitate students' development of evidence-based reasoning and argumentation skills.

Argumentation skills are an important ability, however, several studies on high school students in Indonesia show that argumentation skills still need to be improved significantly. (Sinambela et al., 2023; Hardini & Alberida, 2022; Nanda A, Sukamto, 2024; Rakhmawan et al., 2024; Ummiah & Fuadiyah, 2024; Wess & Priemer, 2024). The research also showed that students often struggle to present claims supported by valid

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evidence and scientific reasoning. This finding highlights the need for innovative learning approaches that actively engage students in inquiry, discussion, and problem-solving.

STEM-based learning has been widely researched as an effective approach to improving students' critical thinking, problem-solving, and argumentation skills. Through integrated activities involving science, technology, engineering, and mathematics, students are encouraged to investigate authentic problems and communicate evidence-based solutions. However, many STEM learning models are still dominated by Western-oriented educational approaches and rarely integrate local cultural contexts. As a result, learning activities may be less meaningful for students in culturally diverse regions. Therefore, researchers are increasingly emphasizing the importance of culturally responsive STEM education that connects scientific concepts with local wisdom and sociocultural practices.

West Sumatra is a region rich in culture, containing values that have the potential to support learning and practicing scientific argumentation. One such performance is the Randai art performance. Randai is a traditional Minangkabau folk theater that combines storytelling, dialogue, movement, music, and collaborative discussion. Randai inherently involves communication, reasoning, negotiation of ideas, and advocacy of viewpoints among the actors, which aligns with the core components of argumentation skills. Integrating Randai into biology learning can provide contextual and culturally meaningful learning experiences for students in West Sumatra (Arsih et al., 2021; Zubaidah & Arsih, 2021). Integrating Randai into STEM-based biology learning can provide contextual and culturally meaningful learning experiences for students in West Sumatra. Through contextual narratives and collaborative interactions embedded in Randai activities, students can become more engaged in discussing biological phenomena, presenting evidence, and constructing scientific arguments.

Based on this perspective, the STEM-RANDAI model was developed as a contextual problem-solving learning model that integrates STEM education with the cultural values of Randai Minangkabau (Trimayora et al., 2022). This model is designed so that each stage is interrelated by providing an experience for students to practice communicating, critical thinking, and creative thinking in solving problems. The STEM-RANDAI model consists of six phases that are integrated with the Engineering Design Process (EDP) on an ongoing basis: Reciting, Analyzing the problem, Narrating the solution, Doing the solution, Assessing the solution, and Implementing (Arsih et al., 2023; Firdaus et al., 2023). Through collaborative and contextual activities, students are expected to actively construct knowledge, communicate ideas, evaluate evidence, and defend scientific arguments.

The STEM-RANDAI model is effective in improving critical thinking, collaboration, and evidence-based decision-making skills. In this process, learning is not just absorbing information but involves students actively seeking answers and solutions (Hoerudin, 2023) Furthermore, critical thinking, problem-solving, and argumentation skills are essential for young people to actively participate in social and environmental decision-making (Smit et al., 2025). This means they will be directly involved with issues and tasks relevant to daily life or specific scenarios (Broman et al., 2018; Huang et al., 2023). Within the problem-solving learning framework, it allows students to achieve learning outcomes through direct experience and independent learning processes (Asad et al., 2021; Hoerudin, 2023; Yulianti & Multahadah, 2024).

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As a designed learning resource, teaching modules can be very important in developing argumentation skills, where the components of the module: initial information, core components, and appendices (student worksheets, assessments, and reading materials) become guides in the learning process. The learning activities created must challenge students in solving problems using evidence and related to problem solving in daily life.

This study adopts the Toulmin Argumentation Patterns framework developed by Erduran et al., which categorizes argument quality into five levels based on the presence of claims, data, warrants, support, and rebuttals. This framework is widely used to evaluate the quality of scientific argumentation in science education research. (Yossyana et al., 2020)

Students' ability to engage in scientific argumentation is closely related to their understanding of scientific concepts (Putri et al., 2024). Several studies highlight this relationship, emphasizing that a strong understanding of content knowledge is fundamental to constructing high-quality arguments (Syuzita, 2023). Although numerous studies have investigated STEM learning and scientific argumentation, research exploring culturally integrated STEM models that incorporate local wisdom traditions such as Randai in biology learning contexts remains limited.

This study aims to investigate the effectiveness of the STEM-RANDAI model in improving high school students' argumentation skills in biology learning. Based on the background of the problem that has been explained, the research question is how effective is the STEM-RANDAI model in improving students' argumentation skills?.

RESEARCH METHOD

Research Design

The research used was an experimental study using a quasi-experimental method. The design used was a Nonequivalent Control Group Design, as the classes were pre-formed, making randomization of subjects impossible. In its implementation (Table 1), the experimental group was given a learning treatment using a STEM-RANDAI-based teaching module, the positive control group was given a learning treatment using the RANDAI model, while the negative control group received conventional learning commonly used by teachers. The research variable, argumentation skills, was measured using a written test designed based on argumentation skill indicators and validated. Therefore, the data obtained were quantitative. In this study, the researcher acted as both the implementer of the learning treatment and the data collector. To maintain objectivity, the test results were assessed using a standardized assessment rubric. Ethical aspects of the research were also considered by providing information to the school and teachers regarding the research objectives and procedures. All student data was kept confidential and used only for research purposes.

Table 1. Design Effectiveness Test

Classes	Pretest	Treatment	Posttest
Eksperimen	Q1	X1	Q2
Positive Control	Q3	X2	Q4
Negative Control	Q5	X3	Q6

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Description:
X_1 = Treatment with the STEM-RANDAI learning model.
X_2 = Treatment with the RANDAI learning model.
X_3 = Treatment with a hands-on learning model.

The determination of experimental and control classes was carried out by considering the similarity of the teaching teachers and the homogeneity of previous academic scores. The focus of the research is directed at students' ability to develop scientific argumentation skills through the implementation of STEM-RANDAI-based teaching modules. The ability of this argument is measured through the provision of an essay test.

Research Subject
The subjects in this experimental research were students of class X/Phase E at SMAN 10 Padang in the 2025/2026 academic year consisting of 9 classes with a total of 360 students. The research sample was determined using a purposive sampling technique by considering certain criteria relevant to the research objectives. The criteria for determining the sample include: (1) classes taught by the same teacher for biology subjects to control differences in learning treatments, (2) having a relatively homogeneous average academic grade based on the previous semester's report card data, and (3) having a relatively balanced number of students. Based on these criteria, identification was carried out on all population classes, then three classes were selected that best met the criteria, namely classes X-E2 (Eksperimen), X-E3 (Positive Control), and X-E4 (Negative Control) These three classes were then determined as research samples with a total of 120 students.

Experimental Research Procedure
The experimental research procedure is carried out through several stages. First, the preparation stage which includes the selection of sample classes through normality and homogeneity tests from nine population classes, as well as the determination of three classes as research groups, namely the experimental class, the positive control class, and the negative control class. At this stage, learning tools were also prepared in the form of STEM-RANDAI-based biology teaching modules, scientific argumentation skills test instruments based on the Toulmin rubric, and observation sheets for learning implementation.

Second, the entire group was given a pretest to measure initial scientific argumentation skills before treatment. Third, at the treatment stage, the experimental class received learning using the STEM-RANDAI-based teaching module with six phases (*Reciting, Analyzing, Narrating, Doing, Assessing,* and *Implementing*), the positive control class received learning using the RANDAI model, while the negative control class received conventional learning in the form of lectures, questions and answers, and practice questions. The learning materials used in the three classes are the same, namely ecosystem topics, with uniform time allocation so that a fair comparison of 3 JP (3 × 45 minutes) in one meeting.

Fourth, after treatment, all groups were given a posttest with the same instrument as the pretest to find out scientific argumentation skills after treatment. Fifth, the data on the results of the pretest and posttest were analyzed to see the improvement of students' scientific argumentation skills in each group and compare the effectiveness of

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the application of the STEM-RANDAI model with the RANDAI model and conventional learning.

The test results showed that most of the questions were declared valid, although there were some questions that needed to be revised, with a reliability value of 0.83 which was classified as very high. This is in accordance with the view of Arikunto (2019) that instruments with high reliability show consistency of measurement results under different conditions. All questions are in the category of medium difficulty, which is important to maintain balance so that the questions are not too easy or too difficult (Sudjana, 2017). Meanwhile, the differentiating power of the questions showed a variation in quality from adequate to very good, with only one item being classified as bad and needing to be improved, in line with the criteria of Nunnally & Bernstein (1994) which emphasized the importance of differentiating power in separating high-ability and low-ability students. Thus, the essay test instrument developed can be declared valid, reliable, and feasible to be used in experimental research to measure students' scientific argumentation skills, as well as be able to provide valid data on the difference in learning outcomes between the experimental class and the STEM-RANDAI model and the control class. The number of questions used in this study was 8 questions. The number of questions used in this study was 8 questions., the reliability value of the question was 0.83 with a very high category. The reliability coefficient of the essay-based argumentation instrument was categorized as good because the Cronbach's Alpha value exceeded 0.70, which is considered acceptable for educational research instruments (George & Mallery, 2003).

The data in this study was carried out quantitatively through the calculation of the percentage of achievement of students' scientific argumentation skills. Before conducting the hypothesis test, an analysis prerequisite test was first carried out, which included a normality test using *Shapiro-Wilk* and a homogeneity test with *the Levene Test* at a significance level of $\alpha > 0.05$ (Usmadi, 2020), to ensure that the data is normally distributed and has homogeneous variance. Once the prerequisites were met, the data were analyzed using one-way analysis of variance (ANOVA) to determine the differences in scientific argumentation skills between classes (experiments, positive controls, and negative controls). If the ANOVA results show a significant difference in the significance level of $\alpha < 0.05$, then the analysis is continued with *the post hoc Least Significant Difference* (LSD) test to find out more specifically the pairs of the real different groups. This data analysis was carried out with the help of SPSS software version 26.0.

RESULTS AND DISCUSSION

Results

This research was conducted in three classes of X-E SMAN 10 Padang with 120 students each, with the aim of seeing the improvement of argumentation skills through the application of the STEM-RANDAI model. The description of the results of the study is presented based on pretest and posttest data from the experimental class, positive control class, and negative control class. Figure 1. shows a descriptive analysis of students' scientific argumentation skills.

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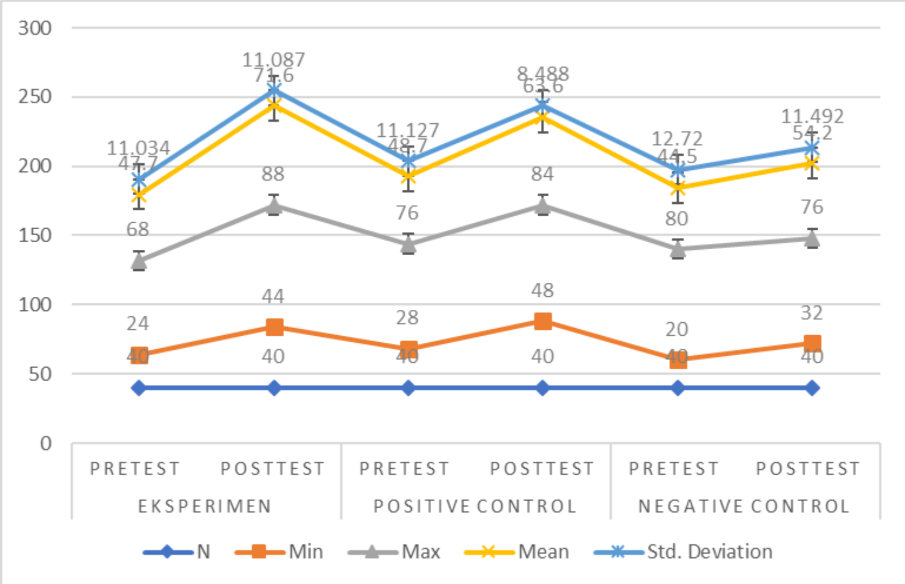

Figure 1. Descriptive Analysis of Argumentation Skills

The results of the descriptive analysis showed that after treatment, the average argumentation skill score of students in the experimental class (71.60; strong criteria) was higher than that of the positive control class (63.60; strong criteria) and the negative control class (54.20; strong criteria). The average increase in scores from pretest to posttest was seen across the class, but the most significant increase occurred in the experimental class. This is also shown in Figure 2 which illustrates the difference in the average between groups, where the experimental class showed the highest achievement of argumentation skills.

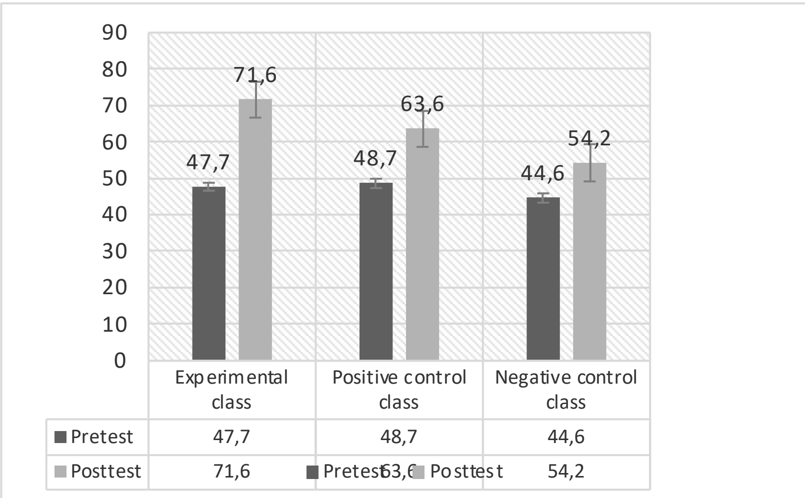

Figure 2. Average Difference in Argument Skills of Each Class

As illustrated in Figure 2, the average score of students' argumentation skills in the experimental class was clearly higher than that of the positive control class and the negative control class. To determine the differences in argumentation skills between groups, a one-way ANOVA test was conducted as shown in Table 2 and Table 3. The results of the analysis showed significant differences between groups

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Table 2. Descriptive Statistics of Argumentation Skills Test Results

Classes		Mean	Std. Deviation	Sig.
Argumentation skills	Eksperimen	23.90	16.934	0.001
	Positive Control	14.90	15.048	
	Kontrol Negatives	9.70	16.773	

Based on the in Table 2, a significance value of $p = 0.001$ ($p < 0.05$) was obtained, indicating a significant difference in argumentation skills between the three treatment groups. Descriptively, the average argumentation skills in the experimental group (M = 23.90; SD = 16.934) were higher than those in the positive control group (M = 14.90; SD = 15.048) and the negative control group (M = 9.70; SD = 16.773).

Table 3. Results of the One-Way ANOVA Test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4129.067	2	2064.533	7.795	.001
Within Groups	30987.600	117	264.851		
Total	35116.667	119			

Furthermore, the results of the one-way ANOVA test in Table 3 indicate a significant difference in argumentation skills between the three treatment groups, with an $F(2, 117)$ value of 7.795 and a significance level of $p = 0.001$ ($p < 0.05$). This difference indicates that learning using the STEM-RANDAI-based learning module provided better results in improving argumentation skills compared to the RANDAI model and conventional learning. To find out which group had the most significant differences, LSD follow-up tests were carried out, the results of which are shown in Table 4.

Table 4. LSD Test Results

(I) Classes	(J) Classes	Mean Difference (I-J)	Sig.
Eksperimen	Positive Control	9.000*	0.015
	Kontrol Negatives	14.200*	0.000
Positive Control	Eksperimen	-9.000*	0.015
	Kontrol Negatives	5.200	0.156
Kontrol Negative	Eksperimen	-14.200*	0.000
	Positive Control	-5.200	0.156

The results of the LSD test in Table 4 indicate that the experimental group had significantly higher argumentation skills than the positive control group (MD = 9.000; $p = 0.015$) and the negative control group (MD = 14.200; $p < 0.001$). In contrast, no significant difference was found between the positive and negative control groups (MD = 5.200; $p = 0.156$). This finding indicates that the integration of the STEM approach into the RANDAI model significantly contributed to improving students' argumentation skills.

Disscussion

The research findings show that the implementation of the STEM-RANDAI model significantly improves students' scientific argumentation skills compared to the RANDAI model and conventional learning. The STEM-RANDAI model is an integrated learning model for Minangkabau culture (Randai art) developed from problem-based learning integrated with the STEM approach. This learning model facilitates students in thinking critically and creatively and combines knowledge, technology, engineering and mathematics. The STEM-RANDAI model also encourages students to solve real-life

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problems, fostering critical thinking and solution-oriented learning. It is highly effective in STEM education, where students learn to apply interdisciplinary knowledge to practical challenges. In addition, the integration of local cultural elements into STEM education makes learning more meaningful and engaging. Problem-solving activities in the STEM-RANDAI model, especially when culturally contextualized, encourage active participation and intrinsic motivation by allowing students to explore problems that are relevant to their cultural identity and community, which is in line with research revealed by (Smith et al., 2022). This advantage is not found in other learning models.

Problem solving through STEM combined with the cultural and performative elements of RANDAI can make learning more engaging and contextually relevant, thereby fostering deeper understanding and argumentation skills (Nhung & Hanh, 2021). Both STEM and RANDAI emphasize collaboration, which is critical for developing argumentation skills through group discussions and evidence-based reasoning (Sapuadi et al., 2025).

The STEM-RANDAI model is designed in several syntaxes. In the learning process at the *reciting* stage (problem orientation) in *Kaba* (story). Students present plays taken from each group and get roles, students who do not do drama observe problems by adhering to the principle of *kato nan ampek* (language manners). For example, students were given a drama related to Sanjai chips, Bukit Tinggi, West Sumatra. In this stage, students process information and focus attention on events so that they can identify the problems presented. This strategy is a step in building students' attention and motivation in the learning process. The integration of STEM into real-world problem-solving and RANDAI's creative storytelling can synergize to enhance critical thinking and the ability to construct logical arguments (Fatihatur Roisah et al., 2025).

Reciting syntax contributes to training students' argumentation skills. In this syntax, the problem is presented in the form of a *Kaba*, also known as a story. Presenting problems in this story form makes it enjoyable for students to understand the problem. Storytelling is often used to clarify problems, provide examples of solutions, and build credibility in arguments. Similarly, in computational argumentation, stories that illustrate solutions to problems have been found to have a positive impact on argument effectiveness, suggesting that storytelling can make arguments more understandable and engaging (Poce et al., 2023; Zijlstra-Shaw & Jowett, 2020). In STEM education, digital storytelling helps students articulate problem statements, understand cost-benefit considerations, and justify solutions, demonstrating its usefulness in developing reasoning skills essential for argumentation. Storytelling is often integrated with rational argumentation to create a morally and logically complex understanding of a problem. This combination allows individuals to use stories to justify their preferences while also engaging in abstract reasoning. Storytelling has been shown to stimulate critical thinking and problem-solving skills. For example, collaborative storytelling activities in educational contexts improve students' ability to analyze, evaluate, and construct arguments.

The aspect of argumentation skills that has the highest classification is the claim that is effectively developed in the learning process at the stage *of analyzing the problem*. This stage involves students formulating questions based on the results of students' identification of the drama (*kaba*) presented. For example, students formulate questions that are relevant to the drama, such as, "What steps can we take as students in overcoming environmental pollution in the form of oil waste from processing Sanjai

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chips, typical of West Sumatra?" The questions generated by these students show that the claim indicator has been optimally achieved. This activity stimulates and trains students' curiosity and skills in studying problem formulations. Students will read *the concepts of Science* (knowledge, facts, procedures) learned using technology by ensuring that the information read is correct and trustworthy. Then the claim level consists of presenting an argument based on the identification of a problem without supporting facts. These findings are in line with (Hardini & Alberida, 2022) which concludes that students can claim an answer from problem solving.

The second syntax, Analyzing the Problem, is also an important step in developing students' argumentation skills. In this step, students critically analyze the problem presented in the form of a story, which in terms of content represents a phenomenon or issue that is contextual and close to life. Contextual and controversial issues, such as socio-scientific issues, provide a rich environment for argumentation. These problems require students to analyze multiple perspectives, justify their reasoning, and engage in evidence-based discussions, which directly enhance their argumentation skills. Analyzing problems in problem-solving activities, especially when combined with a structured framework such as problem-based learning, significantly improves students' argumentation skills (Özcan & Gültekin, 2024). This activity encourages critical thinking, evidence-based reasoning, and collaborative discussion, which are crucial for effective argumentation. This is also the basis for why the second syntax in the STEM-RANDAI model facilitates students' argumentation skills .

In addition to the indicator claiming the highest scientific communication skills, the data indicator also achieved a high score. The basis for effective decision-making is developed during the *Narrating the solution stage*. Students sit together (*sit basamo balapang-lapang*) and discuss *(barundiang*) in formulating innovative ideas for problem solving (investigation). Problem-solving plans are carried out through experiments (project activities). For example, students from group 1 in the experimental class formulated a solution idea by turning used cooking oil (oil that has been used repeatedly) in making Sanjai chips into bar soap by utilizing natural ingredients. This stage involves students gathering information to verify the hypotheses they have created from various learning sources to get explanations. This makes students think critically, think creatively, communicate and argue in constructing problem-solving solutions by paying attention to the use of *Technology, Engineering,* and *Mathematics* in solving problems effectively. According to Masek and Yamin (2021), the basis of decision-making is the ability to evaluate the credibility of sources and the ability to interpret and assess the information obtained.

Students who argue using claim indicators, data, and warrants. This means that students can express an opinion accompanied by data and the link between claims and data. Warrant is the third indicator that often appears at the *Doing the solution* stage. At this stage, students prove claims and data, each group carries out activities in accordance with the solution design during the investigation/observation phase in the learning process. The essence of this activity involves students in conducting investigations in solving problems by paying attention to the use of *Technology, Engineering,* and *Mathematics*. Problem solving is carried out through project activities. For example, group 1 in the experimental class processed used cooking oil using natural ingredients such as lemongrass, pandan leaves and charcoal to make it into bar soap. Research (Dedet Agus Setiawan & Muhyiatul Fadilah, 2023) shows that students in the

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experimental class have reached the level of claims, data and warrants so that there is sufficient proof in scientific arguments.

In the stage *of assessing the solution,* the *backing* and *rebuttal levels are the submission of arguments consisting of a further explanation of* the claim level, data, warrants, backing *that supports* the warrant *and* rebuttal *in the form of conclusions or rebuttals* from all levels. Each group tests the product created in accordance with the design for a solution related to problem solving. Then each group discusses (*barundiang*) through the principle *of bulek kato dek consensus* to make a conclusion on the achievement of problem solving results. Students write in the form of reports and present and communicate the results of the investigation by boldly expressing their opinions (*barani bapandapek*). Students carry out reflection activities, assess, and evaluate the strengths and weaknesses of all processes that have been developed. The last stage *of Implementing* where students apply solutions to similar problems.

Specifically, the STEM-RANDAI module has been proven to be able to facilitate students to reach an advanced level in the argumentation structure of Toulmin (2003), namely *backing* and *rebuttal*. This is in line with the research of Rawe et al. (2025) and Purwati et al. (2019), which reported that students in general still have difficulty composing rebuttals and strengthening arguments (*backing*) due to limited data and scientific knowledge. In this study, activities in the *doing the solution* and *assessing the solution* phases were proven to encourage students to re-examine the data, strengthen the evidence, and present clearer rebuttals. Thus, STEM-RANDAI not only supports the achievement of basic aspects of argumentation (claims, data, reasons), but also directs students to more complex levels of argumentation.

In addition, these results are consistent with the findings of Riwayani et al. (2019), who stated that the quality of students' arguments is often still weak despite being able to formulate a rebuttal, due to the lack of support for scientific concepts. The STEM-RANDAI model is able to overcome these weaknesses by providing a space for collaborative discussion and repetitive investigative practices. This is also in line with the report of Gao et al. (2024) that argumentation skills can be improved through learning that emphasizes investigation and scientific communication based on real problems.

Another advantage of this research is the integration of Randai culture in STEM learning. Randai's typical activities, such as *kaba narration*, sit-down basamo *discussions*, and visual representations, have been proven to contribute to strengthening students' argumentation skills. These results support the research of Wahyu et al. (2025), Dini & Rini (2024), and Nurhairani et al. (2024) who affirm that the integration of local culture in science learning is able to increase students' motivation, engagement, and conceptual understanding. Thus, the novelty of this research lies in the integration of STEM with the local culture of Randai which is not only contextual, but also able to enrich the quality of students' scientific arguments.

Overall, the results of this study confirm that the STEM-RANDAI model is an effective and innovative approach to improve students' scientific argumentation skills in biology learning. The integration of STEM with local culture not only encourages the achievement of basic aspects of argumentation, but also strengthens advanced levels of argumentation that are often failed to be achieved in conventional learning (Nisak & Antika, 2024), (Lutfiani et al., 2024) This research makes an important contribution to the development of learning strategies that are in line with the demands of the

Independent Curriculum, which emphasizes critical thinking, scientific communication, and evidence-based decision-making (Nabella et al., 2024)

However, this research has limitations in the scope of the material, namely it is only focused on ecosystem topics, and its implementation is limited to one school. Therefore, these findings need to be further tested in other biology materials as well as in different schools to obtain a more comprehensive picture of the effectiveness of the STEM-RANDAI model in improving argumentation skills.

CONCLUSION

Fundamental Finding: This study confirms the novelty of integrating the STEM approach with Randai local wisdom in biology learning through the STEM-RANDAI model. Key findings indicate that this model is significantly more effective in improving students' scientific argumentation skills compared to conventional learning or culture-based models alone. This improvement is particularly evident in students' ability to construct advanced arguments, such as constructing evidence-based support and rebuttal, which are important indicators in scientific argumentation. The integration of collaborative and contextual elements of Randai with the STEM approach enables students to understand concepts more meaningfully and develop evidence-based reasoning more optimally. This study establishes the novelty of integrating STEM with local cultural practices through the STEM-RANDAI model in biology learning. Findings indicate that this model significantly improves students' scientific argumentation skills beyond conventional and culture-based approaches. This suggests that integrating STEM in a culturally contextual and collaborative learning environment effectively promotes deeper scientific reasoning and argumentation skills. **Implications:** These findings provide theoretical and practical contributions to science education, demonstrating that combining the STEM framework and local wisdom can be an innovative pedagogical strategy that supports the demands of the Independent Curriculum and 21st-century skills. The implementation of STEM-RANDAI provides a contextual, collaborative, and meaningful learning experience, while strengthening argumentation skills as an aspect of scientific communication. The results of this study indicate that the implementation of the STEM-RANDAI model can be an innovative alternative in biology learning to improve students' argumentation skills. The integration of the STEM approach with local wisdom through the RANDAI model provides a contextual and meaningful learning experience, thus encouraging students to develop critical thinking and argumentative skills. Therefore, this model has the potential to be implemented more widely in science learning in secondary schools.. **Limitation:** This study has limitations in terms of the instruments used. Measurement of argumentation ability is still limited to using written test instruments, so it does not fully reflect students' argumentation abilities in oral or discussion contexts. **Future Research:** Based on these limitations, further research is recommended to involve a broader sample from various schools with different characteristics to increase the generalizability of the findings. Furthermore, further research can combine data collection techniques, such as observation and interviews, to obtain a more comprehensive picture of argumentation skills. This research also opens up opportunities to develop and implement the STEM-RANDAI model in other biology materials or different science fields, thereby enriching learning innovations based on

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local wisdom. This research also provides a new variation in implementing biology or science learning without abandoning the context of cultural values in science learning..

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