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Implementation of the 6E-STEAM Learning Model Based on Nosiala Pale Local Wisdom: Analysis of Learning Outcomes and Student Motivation and Engagement Profiles

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ABSTRACT: This study aims to analyze learning outcomes and describe the motivation and engagement profiles of students following the implementation of the 6E-STEAM learning model based on the local wisdom of Nosiala Pale in biology instruction. The study employed a quantitative approach in a single control class using a pretest-posttest design for learning outcomes and a posttest to assess students' motivation and engagement profiles. The study participants consisted of 28 students in the Biology Education Program who were taking the Conservation Biology course. Data were collected using a 30-item multiple-choice test to measure learning outcomes, as well as a questionnaire to measure students' learning motivation and engagement. Data were analyzed using descriptive statistics, a paired-sample t-test, and N-gain analysis. The results showed that the average pre-test score was 67.38, while the average post-test score was 79.16. The results of the paired-sample t-test indicated a significant difference between the pre-test and post-test learning outcomes ($t = -10.981$; $p < 0.001$). The average N-gain value of 0.480, or 47.95%, falls into the moderate category. Meanwhile, student learning motivation falls into the very high category with an average score of 4.31, and student engagement falls into the high category with an average score of 3.94. These findings indicate that the implementation of the 6E-STEAM learning model based on Nosiala local wisdom is effective in improving student learning outcomes to a moderate level and is supported by high levels of student learning motivation and engagement.

KEYWORDS: 6E-STEAM, Nosiala Pale Local Wisdom, Learning Outcomes, Learning Motivation, Student Engagement

INTRODUCTION

Biology education in higher education focuses not only on mastering concepts but also on strengthening critical thinking skills, fostering motivation to learn, and encouraging students' active engagement in the learning process. The demands of 21st-century learning emphasize the importance of using contextual, participatory (Fitrianto & Farisi, 2025), and student-centered learning models. In this context, the STEAM approach emerges as an integrative approach that connects science, technology, engineering, art, and mathematics within authentic, creative, and problem-solving-based learning experiences. Furthermore, the integration of local wisdom, such as the Nosiala Pale tradition, serves to link abstract scientific principles with cultural contexts that are close to students' lives, thereby bridging the gap between local knowledge and modern academic studies (Julianti et al., 2025; Lathifah et al., 2025).

One relevant model to support this approach is the 6E learning model. This model promotes cycle-based learning through the stages of Engage, Explore, Explain, Elaborate, Enrich, and Evaluate. Through these stages, students not only receive information but also construct knowledge through exploration, discussion, application of concepts, and reflection. As the implementation of 6E-STEAM-based learning evolves, challenges arise in effectively integrating these concepts into rich local cultural contexts, such as Nosiala Pale. Local wisdom is not only a cultural identity but also holds potential as a learning resource capable of enriching students' experiences and enhancing their motivation during the learning process (Pamungkas et al., 2023; Subayani et al., 2025). Furthermore, integrating local wisdom into learning is crucial because it can strengthen the relevance of the material, connect concepts to real-life situations, and support culturally responsive learning (Fitrianto & Farisi, 2025).

Nosiala Pale is a local wisdom value originating from Central Sulawesi, Indonesia, that emphasizes the importance of mutual cooperation, collective responsibility, social solidarity, and environmental stewardship (Wulandari & Mangandar, 2021). These values are reflected in various community practices that prioritize cooperation and shared responsibility in addressing social and environmental issues for the common good. These values are highly relevant to 21st-century educational goals, particularly in developing students' collaboration, communication, problem-solving, and active participation skills. In the context of biology education, particularly Conservation Biology, Nosiala Pale provides a meaningful cultural framework to help students connect scientific concepts with real-world environmental issues and local community practices (Damopili, et al, 2023). Integrating these values into the learning process not only enhances students' conceptual understanding but also fosters ecological awareness, social responsibility, and active engagement in learning activities (Harefa, 2024).

In this study, the local wisdom of Nosiala Pale was used as a learning context to strengthen the connection between concepts in conservation biology and the students' local cultural reality. In addition to learning outcomes, two key aspects that determine the quality of learning are student motivation and engagement. Student motivation and engagement play a crucial role because both directly influence learning outcomes and the overall success of the educational process (Eriyanto et al., 2021). Learning motivation functions as an internal drive that directs students to engage in the learning process, while student engagement reflects behavioral, emotional, and cognitive participation in learning activities (Dalimunthe et al., 2024, Huang & Yang, 2021). Therefore, integrating local wisdom into innovative learning models provides an opportunity to create meaningful learning experiences while supporting academic achievement and student engagement in learning.

Although various studies have reported the success of the 5E and 6E learning models in improving students' conceptual understanding, critical thinking skills, science literacy, and problem-solving abilities, these studies generally still focus on the application of the learning cycle as a pedagogical strategy without comprehensively integrating it with the STEAM approach and local wisdom (Astuti, et al, 2020; Juliyastuti, et al, 2026; Setiawan, et al, 2023). On the other hand, a number of studies also indicate that the STEAM approach can enhance creativity, collaboration, interdisciplinary thinking, and 21st-century skills (Misbah, et al, 2024; Sumarni, et al, 2025).. Similarly, the integration of local wisdom into science learning has been proven to increase the relevance of the material, strengthen students' cultural identity, and create a more contextual learning experience (Kasi, et al, 2022). However, most of these studies still examine the 5E or 6E models, the STEAM approach, and local wisdom as standalone components or merely combine specific pairs of components. To date, research integrating the 6E learning model, the STEAM approach, and local wisdom into a single, comprehensive learning framework remains very limited, particularly in the context of Conservation Biology education at the university level.

The novelty of this study lies in the integration of the 6E learning model, the STEAM approach, and the local wisdom of Nosiala Pale into a single systematic learning framework within the Conservation Biology course. Unlike previous studies, which generally focused only on the effectiveness of the 5E or 6E model, the application of STEAM, or the integration of local wisdom separately, this study combines these three components to create a more contextual, collaborative, and meaningful learning experience. Furthermore, this study not only evaluates student learning outcomes through a comparison of pre-test and post-test scores but also describes students' learning motivation profiles and engagement levels following the implementation of the learning model. Thus, this study is expected to provide theoretical and practical contributions to the development of innovative science education that is culturally grounded and supports the attainment of 21st-century competencies.

Research Questions

Based on the research gap and objectives of the study, the following research questions were formulated:

a) Is there a significant difference in students' learning outcomes before and after the implementation of the 6E-STEAM learning model based on Nosiala Pale local wisdom?
b) What are the profiles of students' learning motivation following the implementation of the 6E-STEAM learning model based on Nosiala Pale local wisdom?
c) What are the profiles of students' engagement following the implementation of the 6E-STEAM learning model based on Nosiala Pale local wisdom?

Research Objective

The objective of this studi are to:

a) Analyze student learning outcomes by comparing pre-test and post-test scores following the implementation of the 6E-STEAM learning model based on the local wisdom of Nosiala Pale.
b) Describe students' learning motivation following the implementation of the learning model.
c) Describe students' engagement following the implementation of the learning model.

Research Hypotheses

To examine changes in students' learning outcomes following the implementation of the 6E-STEAM learning model based on Nosiala Pale local wisdom, the following hypotheses were formulated:

H0: There is no difference in student learning outcomes before and after the implementation of the 6E-STEAM learning model based on the local wisdom of Nosiala Pale.

H1: There is a difference in student learning outcomes before and after the implementation of the 6E-STEAM learning model based on the local wisdom of Nosiala Pale.

LITERATURE REVIEW

This literature review outlines the fundamental concepts underlying the implementation of the 6E-STEAM learning model based on the local wisdom of Nosiala Pale, as well as the relationship between these concepts and student motivation and engagement. The 6E-STEAM learning model was developed as an interdisciplinary approach emphasizing six main stages: Engage (capturing interest), Explore (investigating), Explain (clarifying), Elaborate (developing concepts), Enrich (expanding), and Evaluate (assessing). This approach aims to enhance active and meaningful learning processes through the integration of STEM and arts by incorporating local contexts as the primary learning resources.

The use of local wisdom in learning—specifically Nosiala Pale, which represents the traditional culture and knowledge of the people of Central Sulawesi—is believed to enhance the relevance and depth of students' understanding of the material being studied and to strengthen their cultural identity. Empirically, the application of this model has demonstrated its potential to motivate students through a contextual and meaningful approach, which ultimately increases their active engagement in the learning process. (Pramasdyahsari et al., 2024). Furthermore, theories of motivation and engagement developed by experts such as Schunk and Fredricks support the importance of cultural and local environmental factors in creating learning experiences that engage students' emotional and cognitive aspects. (Anyichie & Butler, 2023).

The 6E-STEAM Learning Model

The 6E-STEAM Learning Model is an innovative approach designed to integrate six stages: Engage (capturing attention), Explore (exploring), Explain (explaining), Elaborate (developing), Enrich (enriching), and Evaluate (assessing)(Şahin & KILIÇ, 2023). This approach is interactive and student-centered, requiring active participation from students in the learning process. The 6E-STEAM concept combines aspects of science, technology, engineering, art, mathematics, and local wisdom, thereby providing a learning experience that is contextual and relevant to the local culture.

In practice, each stage plays a strategic role. The Engage stage aims to spark interest and connect the material to real-world experiences, particularly through an introduction to the elements of Nosiala Pale's local wisdom, which constitute a culturally rich asset. In the Explore stage, students are guided to conduct investigations and experiments that encourage independent and collaborative discovery. The Explain stage focuses on discussion and elaboration of concepts based on the results of exploration, reinforced through visual media and interactive discussions. Next, the Elaborate stage encourages students to apply their knowledge in broader and more creative contexts, including the development of innovations that leverage the values of local wisdom. The Enrich stage is designed to deepen students' understanding of the discussed material through learning resources, whether online or offline. Evaluation is conducted continuously, through assignments and discussions that assess students' comprehension and analytical skills.(Shobri et al., 2021; Suardana et al., 2018). Through this model, the learning process is not only oriented toward academic achievement but also toward character development and innovation rooted in local culture. The entire process is expected to enhance motivation, active engagement, and deep understanding, with the aim of producing graduates who are not only academically intelligent but also capable of valuing local wisdom as an integral part of national identity.By harmonizing the STEAM framework—which synergizes Science, Technology, Engineering, Arts, and Mathematics—with the 6E learning cycle, this model creates a robust, multidisciplinary pedagogical structure. The STEAM approach fosters interdisciplinary connections by emphasizing experiential learning and creative problem-solving (Pramasdyahsari et al., 2024).

Beyond the structural design of these six stages, the effective operationalization of this 6E-STEAM model relies heavily on targeted professional development that empowers educators to bridge the epistemic gap between traditional knowledge systems and contemporary scientific curricula (Sofianidis et al., 2025).Furthermore, the integration of local wisdom within the Elaborate and Enrich stages enables students to transform theoretical interdisciplinary knowledge into social action, thereby bridging the divide between classroom learning and the values inherent in local socio-cultural practices (Effendi et al., 2025).Through meaningful discussions on the practical application of these values, this model can encourage students to internalize local heritage while enhancing their critical thinking and self-regulation skills. This alignment with the foundational theory of STEAM demonstrates that interdisciplinary integration through the synthesis of scientific principles with the arts fosters the creation of a more accessible and cognitively stimulating environment, which directly influences learning outcomes (Marín et al., 2021) . Such an approach can boost student motivation by linking abstract academic concepts to facts relevant to students' circumstances. This connection fosters conceptual understanding, thereby increasing students' active engagement in the learning process (Kong, 2021). Furthermore, the implementation of pedagogical strategies aligned with local values and culture can create a learning environment that leverages relevance and identity as sources of motivation. These elements play a crucial role not only in improving academic achievement but also in fostering effective self-directed learning behaviors (Anyichie & Butler, 2023).

Local Wisdom of Nosiala Pale

The local wisdom of Nosiala Pale is part of a cultural heritage that encompasses a variety of traditional values, belief systems, and social practices passed down from generation to generation by the local community . This wisdom encompasses various aspects, such as culture, customs, traditional knowledge, and collaborative problem-solving methods, which are distinctive characteristics of the Nosiala Pale community. In the fields of education and student character development, this local wisdom plays a strategic role as a learning resource that can strengthen cultural identity while fostering an attitude of appreciation for local wisdom as an important part of the nation's cultural wealth.

Furthermore, Nosiala Pale is not merely a form of inherited knowledge, but also embodies moral and ethical values that can be applied in daily life. Values such as family solidarity, mutual cooperation, and the courage to make decisions based on local wisdom form the foundation for shaping students' character and positive attitudes. Integrating these concepts of local wisdom into the learning model is expected to enhance the relevance of the material and strengthen students' connection to local culture, while also fostering appreciation for Indonesia's cultural diversity.

The development of a learning model based on the local wisdom of Nosiala Pale indirectly helps students recognize, understand, and appreciate the local wisdom of their region, while also encouraging them to integrate these values into modern life. Therefore, the incorporation of local cultural elements into learning activities not only contributes to enhanced academic understanding but also fosters a sense of pride in one's own culture and strengthens national identity (Rasidi & Istiningsih, 2025). Furthermore, the application of local wisdom values in the educational process is expected to shape students who are not only academically excellent but also possess a character that reflects the noble values inherited from their local culture.

Student Motivation and Engagement

Student motivation and engagement are key factors that can influence the success of implementing the 6E-STEAM learning model based on the local wisdom of Nosiala Pale. Based on several previous studies, it has been found that students' intrinsic motivation tends to increase through an approach that integrates aspects of local wisdom into the learning process(Pamungkas et al., 2023; Shufa & Adji, 2024). This approach is capable of sparking curiosity and pride in the local culture, so that students feel more interested and motivated to actively participate.

In addition, student engagement can be observed through their active participation in various learning activities, such as discussions, collaboration on group projects, and the presentation of their work. The implementation of this learning model creates a more dynamic and engaging learning environment, making students feel valued and responsible for their own learning process. Based on survey results and observations, the clarity of learning objectives and the relevance of the material to local culture have proven to play a significant role in substantially increasing student motivation and participation.(Khatter et al., 2024) .

Success in boosting learning motivation is also supported by the implementation of contextual learning through the integration of the values and meanings of the Nosiala Pale local wisdom into the 6E-STEAM learning framework. This integration enables students to connect academic concepts with the social and cultural realities they are familiar with, making learning more relevant and meaningful. This contributes to increased student confidence, interest, and enthusiasm in the learning process.

In general, the data indicate a positive correlation between student motivation and engagement and the implementation of the 6E-STEAM learning model based on the local wisdom of Nosiala Pale.(Pamenang, 2021; Sumarni et al., 2025) . This confirms that strategies integrating local cultural aspects into learning models not only provide enjoyable and meaningful learning experiences but also enhance student motivation and active participation. Thus, the development of learning that is sensitive to the local cultural context plays a crucial role in improving the quality of the higher education process.

METHODOLOGY

Study Design and Setting

This study employed a quantitative approach using a one-group pre-test–post-test design to examine students' learning outcomes before and after the implementation of the 6E-STEAM learning model based on Nosiala Pale local wisdom. In addition, a post-test-only design was used to describe students' learning motivation and engagement following the implementation of the learning model. The study was conducted in the Conservation Biology course within the Biology Education Program at a university in Indonesia.

The instructional intervention integrated the 6E learning cycle (Engage, Explore, Explain, Elaborate, Enrich, and Evaluate), the STEAM approach (Science, Technology, Engineering, Arts, and Mathematics), and the local wisdom values of Nosiala Pale. Throughout the learning process, students were engaged in identifying conservation issues, exploring environmental phenomena, discussing scientific concepts, designing project-based solutions, and reflecting on learning outcomes. The values of Nosiala Pale, including mutual cooperation, collective responsibility, social solidarity, and environmental stewardship, were embedded within learning activities to strengthen the connection between conservation biology concepts and local cultural contexts.

Participants

The participants consisted of 28 undergraduate students enrolled in the Conservation Biology course in the Biology Education Program. Since all students in the class participated in the study, a total sampling technique was employed. The participants were selected because they were directly involved in the implementation of the 6E-STEAM learning model based on Nosiala Pale local wisdom.

Data Collection

Data were collected using three research instruments: a learning outcomes test, a learning motivation questionnaire, and a student engagement questionnaire.

The learning outcomes test consisted of 30 multiple-choice items administered as both a pre-test and a post-test to assess students' cognitive achievement in conservation biology. The test covered topics related to biodiversity conservation, ecosystem management, environmental threats, and sustainable development.

Students' learning motivation was measured using a questionnaire consisting of 25 items rated on a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5). Similarly, student engagement was measured using a 25-item questionnaire employing the same five-point Likert scale. The engagement questionnaire assessed students' behavioral, emotional, and cognitive engagement during the learning process. Prior to data collection, all research instruments were reviewed and validated by experts to ensure their relevance, clarity, and suitability for measuring the intended constructs.

The data collection procedure was conducted in four stages. First, students completed a pre-test to determine their initial understanding of conservation biology concepts. Second, the 6E-STEAM learning model based on Nosiala Pale local wisdom was implemented during the instructional period. Third, students completed a post-test to measure their learning outcomes after the intervention. Finally, learning motivation and student engagement questionnaires were administered at the end of the learning process.

Statistical or Analytical Methods

The collected data were analyzed using descriptive and inferential statistics. Learning outcomes data were analyzed using descriptive statistics, including minimum scores, maximum scores, means, and standard deviations. Before hypothesis testing, a normality test was conducted to examine whether the data were normally distributed. Differences between pre-test and post-test scores were analyzed using a paired-sample t-test at a significance level of 0.05. In addition, normalized gain (N-gain) analysis was performed to determine the magnitude of improvement in students' learning outcomes following the implementation of the learning model.

Data obtained from the learning motivation and student engagement questionnaires were analyzed descriptively using means, percentages, and score categories. The interpretation of mean scores was based on a five-point Likert scale. Category intervals were determined using the formula (maximum score − minimum score) ÷ number of categories. With a score range of 1–5 and five categories, the interval width was 0.80. Accordingly, the scores were classified into five categories: very low (1.00–1.80), low (1.81–2.60), moderate (2.61–3.40), high (3.41–4.20), and very high (4.21–5.00).

RESULT

Student Learning Outcomes

a) Descriptive Data

Table 1. Descriptive Statistics of Student Learning Outcomes

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Pre-test	28	46,67	83,33	67,38	9,042
Post-test	28	66,67	90,00	79,16	6,704

According to Table 1, the students' average pre-test score was 67.38, while the average post-test score increased to 79.16. Thus, there was an average increase of 11.78 points following the implementation of the 6E-STEAM learning model based on the local wisdom of Nosiala Pale. Additionally, the standard deviation in the post-test was lower than that in the pre-test, indicating that the variation in students' learning outcomes after the instruction became more homogeneous.

b) Normality Test

Table 2. Results of the Shapiro-Wilk Test for Data Normality

Variable	Shapiro-Wilk	Sig.	Description
Pre-test	0,955	0,257	Normally distributed
Post-test	0,945	0,151	Normally distributed

The results of the Shapiro-Wilk normality test indicate that the significance values for the pre-test (p = 0.226) and post-test (p = 0.141) are greater than 0.05. Therefore, the pre-test and post-test data are normally distributed, so the analysis can proceed using a parametric test, specifically the paired-sample t-test.

c) Paired-Sample T-Test

Table 3. Results of the Paired-Sample T-Test

Data Pairs	Mean Difference	t	df	Sig. (2-tailed)	Description
Pre-test – Post-test	-14,881	-10,981	27	< 0,001	Significant

The results of the paired t-test indicate a significant difference between students' pre-test and post-test scores ($t = -10.981$; $df = 27$; $p < 0.001$). Thus, the null hypothesis (H_0) is rejected and the alternative hypothesis (H_1) is accepted. These results indicate that students' learning outcomes after participating in instruction using the 6E-STEAM model based on the local wisdom of Nosiala Pale were significantly higher than before the instruction.

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d) N-Gain Test

Table 4. Results of the N-Gain Analysis of Student Learning Outcomes

	N	Minimum	Maximum	Mean	Standar Deviation
N-Gain Score	28	-0,50	1,00	0,480	0,363
N-Gain Persen	28	-50,04	100,000	47,95	36,35
Valid N	28				

The average N-gain score was 0.480, which falls within the moderate category. These results indicate a moderate improvement in students' learning outcomes following the implementation of the 6E-STEAM learning model based on Nosiala Pale local wisdom. Although variations were observed among individual students, the overall findings suggest that the learning model contributed positively to students' understanding of conservation biology concepts.

e) Student Motivation to Learn

Table 5. Descriptive Statistics on Student Motivation to Learn

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Total score	28	81,00	125,00	107,68	10,37
Average score	28	3,24	5,00	4,30	0,41

Table 5 shows that students obtained an average motivation score of 4.30 out of 5.00, indicating a high level of learning motivation following the implementation of the learning model.

Table 6. Distribution of Student Learning Motivation Categories

Average interval	Category	Frequency	Percentage (%)
1,00-1,80	Very low	0	0,0
1,81-2,60	Low	0	0,0
2,61-3,40	Moderate	1	3,6
3,41-4,20	High	10	35,7
4,21-5,00	Very high	17	60,7
Total		**28**	**100,0**

Most students were categorized as having very high learning motivation (60.7%), followed by high motivation (35.7%). Only one student (3.6%) was classified in the moderate category, while no students were classified in the low or very low categories. Overall, students demonstrated a very high level of learning motivation following participation in the 6E-STEAM learning model based on Nosiala Pale local wisdom.

f) Student Participation

Table 7. Descriptive Statistics on Student Participation

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Total score	28	75,00	125,00	98,43	13,01
Average score	28	3,00	5,00	3,94	0,52

The average student participant score was 3.94, indicating a high level of engagement following the implementation of the learning model.

Table 8. Distribution of Student Participation Categories

Average interval	Category	Frequency	Percentage (%)
1,00-1,80	Very low	0	0,0
1,81-2,60	Low	0	0,0
2,61-3,40	Moderate	5	17,9
3,41-4,20	High	15	53,6
4,21-5,00	Very high	8	28,6
Total		**28**	**100,00**

The majority of students were classified in the high (53.6%) and very high (28.6%) engagement categories. Overall, students demonstrated a high level of engagement following the implementation of the learning model. Since no pre-test data were collected for this variable, the findings describe students' engagement profiles after the intervention and should not be interpreted as evidence of improvement.

DISCUSSION

The Contribution of the Nosiala Pale-Based 6E-STEAM Learning Model to Student Learning Outcomes

The findings revealed a significant improvement in students' learning outcomes following the implementation of the 6E-STEAM learning model based on Nosiala Pale local wisdom. The paired-sample t-test indicated a statistically significant difference between pre-test and post-test scores, while the N-gain analysis showed a moderate level of improvement. These findings suggest that the integration of the 6E learning cycle, the STEAM approach, and local wisdom created meaningful learning experiences that facilitated students' understanding of conservation biology concepts.

The improvement in learning outcomes can be explained through the constructivist nature of the 6E learning cycle. During the Engage and Explore phases, students actively interacted with authentic conservation issues and local environmental phenomena, allowing them to construct knowledge based on their prior experiences. The Explain, Elaborate, and Enrich stages further encouraged students to refine their understanding through discussion, collaboration, and project-based activities. Such learning experiences are consistent with constructivist theory, which emphasizes that knowledge is actively constructed through interaction with the environment and social experiences.

The results are consistent with previous studies reporting that 5E and 6E learning cycle models contribute positively to students' conceptual understanding, critical thinking skills, and scientific literacy (Astuti et al., 2020; Setiawan et al., 2023; Juliyastuti et al., 2026). Similarly, STEAM-based learning has been shown to enhance interdisciplinary thinking, creativity, and problem-solving skills by connecting scientific concepts with real-world applications (Misbah et al., 2024; Sumarni et al., 2025). In the present study, these benefits were strengthened through the integration of Nosiala Pale local wisdom, which provided culturally meaningful contexts that enabled students to connect scientific knowledge with local environmental realities.

An important contribution of this study is that it demonstrates the feasibility of integrating local wisdom into a 6E-STEAM framework within higher education conservation biology courses. While previous studies generally examined learning cycles, STEAM, or local wisdom separately, this study shows that combining these elements can support both academic achievement and contextual understanding.

Student Learning Motivation Following the Implementation of the Learning Model

The findings showed that students demonstrated a very high level of learning motivation following participation in the 6E-STEAM learning model based on Nosiala Pale local wisdom. Most students were categorized in the very high and high motivation categories, indicating that the learning environment successfully stimulated students' interest and willingness to engage in learning activities.

One possible explanation for this finding is that the learning activities were closely connected to students' cultural backgrounds and local environmental contexts. Contextual learning is known to increase students' perceptions of relevance, which is a key factor influencing motivation. When students perceive learning materials as meaningful and applicable to their daily lives, they are more likely to develop positive attitudes toward learning and sustain their effort throughout the instructional process.

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These findings support previous studies suggesting that the integration of local wisdom into science learning can strengthen students' motivation by increasing cultural relevance and personal connection to the learning content (Pamungkas et al., 2023; Shufa & Adji, 2024). Furthermore, culturally responsive learning environments have been reported to enhance students' sense of belonging and learning interest, thereby contributing to stronger intrinsic motivation.

The STEAM approach may also have contributed to the high motivation levels observed in this study. By involving students in inquiry activities, collaborative projects, and creative problem-solving tasks, STEAM learning provides opportunities for autonomy, exploration, and self-expression. Such experiences are widely recognized as important determinants of learning motivation.

Student Participant in a Culturally Responsive Learning Environment

The results indicated that students demonstrated a high level of engagement following the implementation of the learning model. Most students were categorized in the high and very high engagement categories, suggesting active participation in learning activities. Student partcipant can be interpreted as a reflection of students' behavioral, emotional, and cognitive involvement in learning. The collaborative nature of the 6E-STEAM learning model encouraged students to participate actively in discussions, investigations, and project development activities. At the same time, the incorporation of Nosiala Pale values such as mutual cooperation and collective responsibility promoted meaningful social interaction among students.

These findings are consistent with previous studies indicating that active and contextual learning environments can strengthen student engagement by creating opportunities for collaboration, inquiry, and authentic problem-solving (Khatter et al., 2024). Similarly, ethnoscience-based and culturally responsive learning approaches have been shown to increase students' participation and responsiveness during science learning activities (Rofi'i et al., 2022; Amelia & Khairuna, 2025).

It is important to note that engagement was measured only after the implementation of the learning model. Therefore, the findings describe students' engagement profiles rather than demonstrating improvement. Nevertheless, the high level of engagement observed suggests that the learning environment created through the integration of 6E-STEAM and Nosiala Pale local wisdom was conducive to active participation and meaningful learning experiences.

Strengths and Limitations of the Study

This study has several strengths. First, it integrates the 6E learning cycle, the STEAM approach, and Nosiala Pale local wisdom into a single instructional framework. Second, the study was conducted within the context of conservation biology, where local environmental and cultural issues are highly relevant to learning objectives. Third, the study examined not only learning outcomes but also students' motivation and engagement profiles.

Despite these strengths, several limitations should be acknowledged. The study employed a one-group pre-test–post-test design without a control group, limiting the ability to establish causal relationships. The sample size was relatively small and drawn from a single study program, which may limit the generalizability of the findings. In addition, motivation and engagement were measured only after the intervention, preventing the analysis of changes over time.

Implications and Future Research Directions

The findings have important implications for biology education and culturally responsive pedagogy. The integration of local wisdom into the 6E-STEAM framework demonstrates a promising strategy for creating meaningful learning experiences that support academic achievement while preserving cultural values. The model may be adapted for use in other science courses and educational contexts where local culture and environmental issues are relevant.

Future studies should employ experimental or quasi-experimental designs involving control groups to provide stronger evidence regarding the effectiveness of the model. Researchers may also investigate changes in motivation and engagement through pre-test and post-test measurements. In addition, future research could examine the influence of the model on other twenty-first-century competencies, such as critical thinking, communication, collaboration, creativity, and environmental literacy.

CONCLUSION

The implementation of the 6E-STEAM learning model based on the local wisdom of Nosiala Pale significantly improved students' learning outcomes. This finding was evidenced by a statistically significant difference between pre-test and post-test

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scores, indicating that students achieved better cognitive performance following the learning intervention. Furthermore, the average N-gain score was classified in the moderate category, suggesting a moderate level of improvement in students' understanding of conservation biology concepts.

In addition to cognitive outcomes, students demonstrated a very high level of learning motivation and a high level of engagement following the implementation of the learning model. These findings indicate that the integration of the 6E learning cycle, the STEAM approach, and Nosiala Pale local wisdom created a meaningful and culturally relevant learning environment that encouraged active participation and positive learning experiences.

Overall, the findings suggest that the 6E-STEAM learning model based on Nosiala Pale local wisdom has the potential to support both academic achievement and positive affective outcomes in conservation biology learning. Future research is recommended to employ experimental or quasi-experimental designs involving control groups, larger sample sizes, and pre-test–post-test measurements of motivation and engagement to provide stronger evidence regarding the effectiveness of the model and its impact on various dimensions of student learning.

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