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Improving Student Achievement in Ecosystem Learning through Environment-Based Culturally Responsive Teaching

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Abstract

Biology learning becomes more meaningful when scientific concepts are linked to students' cultural backgrounds and everyday environments. This classroom action research investigated the impact of Culturally Responsive Teaching (CRT), integrated with local cultural contexts, on students' Biology learning outcomes in ecosystem instruction. The study was conducted in two cycles, each consisting of planning, action, observation, and reflection. Data were collected through learning outcome tests and classroom observations, and were analysed descriptively by comparing student achievement across the pre-cycle, Cycle I, and Cycle II. Results demonstrated progressive improvements in learning outcomes. The average score increased from 43.44 in the pre-cycle to 59.68 in Cycle I and 72.16 in Cycle II. The proportion of students meeting the predetermined mastery criterion rose from 12% to 44% and 84%, respectively. This study contributes by examining CRT implementation in ecosystem learning by connecting biological concepts to students' local cultural experiences and environments. The findings indicate that CRT-based instruction, combined with iterative instructional adjustments, was associated with improved learning outcomes. However, these improvements cannot be attributed solely to CRT, as other instructional changes across cycles may have contributed. This study underscores the potential of context-sensitive Biology instruction to make ecosystem concepts more relevant to students' lived experiences and provides a foundation for further research on CRT implementation in similar educational contexts.

Keywords: *biology learning; ecosystem; culturally responsive teaching; classroom action research; learning outcomes.*

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1. INTRODUCTION

The 21st-century educational paradigm shift requires learning systems to adapt to the dynamics of the Industrial Revolution 4.0. Rapid advances in digital technology require students to develop critical thinking, effective communication, collaboration, and creative skills, key competencies for navigating global competition. In science education, specifically Biology instruction can no longer focus solely on conceptual representation; instead, it must foster both 21st-century skills and environmental literacy. Ogunniyi (2023) emphasises linking science education to students' social and cultural realities, helping them grasp the interconnections among science, technology, and society in their daily lives.

Despite these needs, research demonstrates that instructional practices in Indonesia predominantly utilise conventional, teacher-centred models. These approaches lead to low student engagement and fail to connect learning to relevant cultural and environmental contexts (Firdausy et al., 2024; D. Noviarini & Handayani, 2024; Whatoni et al., 2024). Brown and Crippen (2017) report that science instruction often uses a "one-size-fits-all" strategy, ignoring diverse student backgrounds and hindering students' understanding of scientific concepts. Consistent with these observations, Smith et al. (2022) argue that insufficient cultural sensitivity in science education obstructs the achievement of equitable learning outcomes.

A comparable situation is observed at SMA Negeri 1 Busang in East Kalimantan Province, where Biology instruction on the topic of "Ecosystems" has not yielded optimal outcomes. Recent daily test

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data show that the average student score on this topic was 43.31, significantly below the minimum mastery standard (KKM) of 70. The highest score attained was 72, and the lowest was 8. These results suggest that students have limited understanding of the relationships between biotic and abiotic components and the interactions within ecosystems. This low performance likely reflects instructional methods that do not connect ecological concepts to students' local social and cultural contexts.

Given the issues mentioned above, the Culturally Responsive Teaching (CRT) approach offers a relevant, innovative solution to improve learning outcomes. CRT aligns instructional strategies with students' cultural backgrounds to make learning more relevant and effective (Brown & Crippen, 2016). Through CRT, teachers can use students' cultural experiences and immediate environments as meaningful learning resources, fostering emotional and cognitive connections between students and the subject matter (D. Noviarini & Handayani, 2024; Whatoni et al., 2024).

Existing research shows that Culturally Responsive Teaching (CRT) effectively improves the quality of science education. Brown (2017) observes that integrating culturally responsive pedagogy with inquiry-based science instruction fosters student ownership of learning and promotes equitable access for learners from diverse backgrounds. Putri and Selviari (2024) confirm that incorporating local culture into instruction helps students understand abstract concepts in a contextual, meaningful way. Implementing CRT also increases active student participation by linking instructional material to students' daily lives and habits (Comstock et al., 2023; Khalisah et al., 2023; Rimang et al., 2024). Additionally, Damayanti et al. (2023) and Rahman (2024) indicate that CRT connects students' personal experiences, local culture, and academic concepts, fostering reflective thinking and mutual intercultural respect.

While prior studies indicate that the Culturally Responsive Teaching (CRT) approach increases student engagement, supports comprehension of science concepts, and connects learning materials to local culture, further investigation is necessary to adapt CRT to the specific cultural characteristics and context of students at SMA Negeri 1 Busang. Therefore, this study examines CRT's application by integrating culture and local wisdom into science instruction and assesses its effects on student engagement and understanding. This focus aligns with Brown's (2017) and Ialuna et al. (2025) assertion that culturally responsive teaching is essential for fostering relevant, inclusive, and meaningful educational experiences.

In biology instruction, the Culturally Responsive Teaching (CRT) approach is particularly relevant because it connects ecosystem concepts to students' local contexts. Potocki (2025) highlights the importance of culture-based environmental education in fostering ecological awareness and social responsibility. Furthermore, Akcan (2022) argues that culturally responsive teaching cultivates active, reflective, and empowered learners by affirming students' cultural identities throughout the educational process. Therefore, the CRT approach enhances cognitive learning outcomes while also promoting environmental stewardship and sustainability.

Building on the preceding review, this classroom action research aims to improve Biology learning outcomes related to ecosystems by implementing an environment-based Culturally Responsive Teaching (CRT) approach. The study is expected to contribute empirically to humanistic, contextual, and sustainable teaching practices, aligned with 21st-century educational priorities of social justice and environmental sustainability.

2. METHOD

The present study adopts a classroom action research (CAR) approach. According to Romeli et al. (2023), classroom action research helps enhance instructional quality through carefully designed actions implemented iteratively in cycles of improvement. Anggara and Krisanti (2025) states that CAR enables teachers to identify instructional issues, select corrective actions, and assess their impact through a structured process. Utomo, Asvio, and Prayogi (2024) highlight CAR's practical emphasis, as it addresses

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classroom problems through recurring cycles of planning, observing, and reflecting. Therefore, CAR is a relevant methodology for teachers seeking to reflect on and improve daily instructional practices.

The CAR model applied in this study is based on the spiral model developed by Kemmis and McTaggart (2014). This model was chosen for its practicality and ease of implementation in classroom research contexts. It also provides a clear workflow that helps organise each stage of the research. The Kemmis and McTaggart model supports a systematic and purposeful research process, allowing researchers to plan actions, implement them during instruction, observe the process, and evaluate outcomes through reflection. This structure not only enables the study to be conducted in an organised manner but also enhances the transparency and comprehensibility of the research process. In the Kemmis–McTaggart (2014) model, classroom action research follows four interconnected stages: planning, acting, observing, and reflecting (Burns, 2019; Kemmis & McTaggart, 2014).

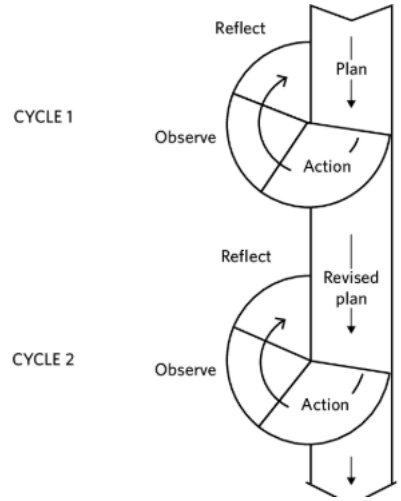

Figure 1. *CAR Kemmis & McTaggart Model (2014)*

According to Figure 1, the Kemmis–McTaggart model begins with the planning stage, in which the researcher formulates research objectives, selects appropriate instructional strategies, and prepares implementation steps for the classroom. The plan is then enacted in the action implementation stage through direct instructional activities. During this phase, the researcher conducts systematic observations to document classroom events, with particular attention to student activities and the effects of the implemented actions. After completing these activities, the researcher enters the reflection stage to review both the process and outcomes. This reflection assesses the action's effectiveness and identifies areas for improvement in the next cycle. The cyclical nature of these stages establishes the Kemmis–McTaggart model as a comprehensive framework for classroom action research.

The researcher used Culturally Responsive Teaching (CRT) by bringing the Menugal tradition, a local rice-planting practice, into each cycle of classroom action research with the Kemmis–McTaggart model. In the planning stage, the researcher and teacher identified relevant biological concepts and linked them to Menugal's cultural practices, knowledge, and environmental experiences in East Kalimantan. They prepared learning materials, lesson plans, worksheets, and assessments that encouraged students to explore how local agricultural practices connect to biology. During the action stage, the researcher used Menugal as a real-life example to help students connect biology to their environment. Students shared what they already knew, discussed the biological processes in traditional rice cultivation, and worked together in group activities. The researcher observed the lessons to record student participation, engagement, and reactions to CRT.

During the reflection stage, the researcher reviewed observations, student assessments, and learning outcomes to see how well the actions worked. After each cycle, the results helped identify learning challenges, check students' understanding of biology, and decide what to improve next. In the

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next cycle, I adjusted teaching strategies by clarifying the link between Menugal and biology, providing clearer explanations, and encouraging more student participation. This process continued into the second cycle, with changes based on earlier reflections. By using this step-by-step approach, the integration of Menugal aimed to make science concepts more meaningful, connect lessons to students' cultural backgrounds, and improve learning results. CRT's goal here was to create a classroom where local knowledge and science support each other.

This study was conducted over two cycles in a Grade XI class at SMA Negeri 1 Busang during the even semester of the 2025/2026 academic year. The study included 25 students: 12 males and 13 females. Assessment was carried out using testing techniques, with evaluations administered at the end of each learning cycle to measure student learning outcomes. The collected data were subsequently analysed using both quantitative and qualitative descriptive approaches. Quantitative analysis involved calculating the average score and the percentage of student mastery for each cycle, while qualitative analysis was used to describe students' levels of engagement, attitudes, and participation based on observational data.

Test scores served as the primary indicator of the study's success. The intervention was considered successful if at least 80% of students achieved a minimum score of 70 on a 0–100 scale, consistent with the curriculum standards at SMA Negeri 1 Busang. The overall level of student learning success was determined using the formula proposed by Rifqi et al. (2024)as follows:

$$Procedure\ Success\ Rate = \frac{\sum N}{\sum S}\ x\ 100\%$$

Information:
$\sum N$ = number of students who achieved mastery
$\sum S$ = total number of students

Table 1. *Criteria for Success of the Intervention*

No	Success Rate (%)	Score Criteria
1	90–100	Very High
2	80–89	High
3	65–79	Moderate
4	55–64	Low
5	0–54	Very Low

3. RESULTS AND DISCUSSION

This study was conducted in Grade XI at SMA Negeri 1 Busang from March to May 2026 during the 2025/2026 academic year. The Classroom Action Research (CAR) method was employed, consisting of a pre-cycle stage, Cycle 1, and Cycle 2. The following sections present the results and discussion for each stage.

3.1 Pre-Cycle Stage

During the pre-cycle stage, each student took an initial assessment (pre-test) on ecosystems, consisting of 30 multiple-choice questions, to gauge their proficiency. The results indicated that most students scored below the Minimum Mastery Criterion (KKM) of 70. The results of the pre-cycle assessment are presented below.

Table 2. *Pre-Cycle Assessment Results*

No	Aspect Observed	Results

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1	Highest Score	72
2	Lowest Score	8
3	Number of Students Who Passed	3
4	Number of Students Who Did Not Pass	22
5	Class Average Score	43,44
6	Percentage of Students Who Passed	12%

Table 2 shows that 22 students failed to meet the mastery standard, while only 3 succeeded, for a mastery rate of 12%. Furthermore, the average score was 43.44, well below the minimum mastery criterion (KKM) of 70. These findings indicate that students in Class XI at SMA Negeri 1 Busang need targeted intervention to improve their learning outcomes on the ecosystem topic in biology.

This situation is further corroborated by preliminary observations showing that instruction was dominated by one-way lectures. This teaching pattern hindered interaction between the teacher and students, leaving students passive and limiting their opportunities to express opinions, ask questions, or connect the lesson material to their own experiences. Consequently, an instructional intervention is needed that goes beyond mere content delivery to foster learning that is contextual and relevant to students' characteristics. One viable alternative is the Culturally Responsive Teaching (CRT) approach, which integrates students' cultural backgrounds, experiences, knowledge, and life contexts into the learning process. Implementing this approach is expected to connect lesson material to students' real lives while boosting their active engagement in learning.

3.2 Cycle 1 Stage

Based on findings from observations and evaluations during the pre-cycle stage, the researcher planned Cycle 1 instruction using the Culturally Responsive Teaching (CRT) approach. The planning phase involved developing a teaching module, guiding questions, instructional materials, student worksheets (LKPD), and an assessment to measure Cycle 1 learning outcomes.

Cycle 1 was conducted over four sessions on April 6, 8, 13, and 15, 2026 (each lasting 70 minutes). In the first session, the teacher introduced ecosystems to students using the CRT approach. Sessions two through four proceeded as follows: deepening the study of ecosystem concepts, completing student worksheets and conducting group presentations, and administering a final assessment (post-test). The post-test instrument used in Cycle 1 consisted of 30 multiple-choice questions.

Assessment and observation results from Cycle 1 indicated improved biology learning outcomes compared to the previous stage. Several students scored above the Minimum Mastery Criterion (KKM) of 70. The assessment results for Cycle 1 are presented below.

Table 3. *Cycle 1 Assessment Results*

No	Aspect Observed	Results
1	Highest Score	76
2	Lowest Score	20
3	Number of Students Who Passed	11
4	Number of Students Who Did Not Pass	14
5	Class Average Score	59,68
6	Percentage of Students Who Passed	44%

Based on Table 3, the post-test results show that 14 students did not meet the mastery criteria, while 11 did, for a mastery rate of 44%. The average class score was 59.68; although this improved from the previous stage, it remains well below the minimum mastery standard (KKM) of 70.

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The improvement in biology learning outcomes during Cycle I was evident not only in the students' scores but also in their increased active participation during the learning process. Students became more confident in asking questions, sharing ideas, and presenting their Student Worksheet (LKPD) activity results in groups. These conditions demonstrate that implementing the Culturally Responsive Teaching (CRT) approach can foster student engagement by linking the subject matter to experiences, environments, and daily lives that are familiar to them.

Based on the reflection from Cycle I, the research proceeded to Cycle II with several improvements made to the learning process. These improvements included strengthening student self-reflection activities, deepening the application of the Culturally Responsive Teaching (CRT) approach through a more thorough exploration of local culture, providing broader opportunities for discussion, and increasing support to ensure all students received equitable guidance during learning activities.

3.3 Cycle 2 Stage

Based on observations and reflections from the previous cycle, the researcher designed Cycle 2 instruction by strengthening the application of the Culturally Responsive Teaching (CRT) approach. The planning phase involved preparing instructional materials and instruments, such as teaching modules, guiding questions, learning resources, and student worksheets (LKPD), tailored to students' characteristics and context. Additionally, the researcher developed assessment instruments to measure and evaluate student learning outcomes following the instruction in Cycle 2.

Cycle 2 was conducted over four sessions on April 22, 27, and 29, 2026, and May 4, 2026 (each lasting 70 minutes). In the first session, the teacher deepened the students' understanding of ecosystems using the CRT approach. The subsequent three sessions involved the following activities in sequence: completing the ecosystem worksheet by exploring the school's surrounding environment, presenting the worksheet results in groups, and taking a final assessment (post-test). The Cycle 2 post-test instrument consisted of 30 multiple-choice questions.

Assessment and observation results from Cycle 2 indicated improved biology learning outcomes compared to Cycle 1. Several students scored above the Minimum Mastery Criterion (KKM) of 70. The assessment results for Cycle 2 are presented below.

Table 4. *Cycle 2 Assessment Results*

No	Aspect Observed	Results
1	Highest Score	84
2	Lowest Score	44
3	Number of Students Who Passed	21
4	Number of Students Who Did Not Pass	4
5	Class Average Score	72,16
6	Percentage of Students Who Passed	84%

Table 4 shows that in Cycle 2, 21 students achieved learning mastery and 4 did not, resulting in a class mastery rate of 84%. This achievement met the established research success indicator, which required at least 80% of students to achieve learning mastery. In addition to class mastery, the students' average learning outcome score was 72.16, exceeding the Minimum Mastery Criterion (KKM) of 70. Thus, the results from Cycle 2 demonstrate that both success indicators a class mastery rate of at least 80% and an average score exceeding the KKM were achieved. Consequently, the instructional intervention implemented in Cycle 2 successfully improved biology learning outcomes on the topic of ecosystems.

Applying Culturally Responsive Teaching (CRT) by integrating the Menugal tradition, a local cultural practice in East Kalimantan, resulted in improved student performance in biology. In Cycle 2, 21 students

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achieved learning mastery, while 4 did not meet the established criteria, resulting in an 84% class mastery rate. This rate exceeded the predetermined success indicator of 80%, indicating that the classroom action research met its criterion for success. Incorporating Menugal, which reflects local knowledge and community practices related to planting and agriculture, provided a meaningful contextual framework for learning about ecosystems. By connecting biological concepts to students' cultural and environmental experiences, the CRT approach better integrated scientific concepts into students' daily lives.

Additionally, the average learning outcome score in Cycle 2 was 72.16, surpassing the Minimum Mastery Criterion (KKM) of 70. These results suggest that implementing CRT based on the Menugal tradition positively influenced students' learning outcomes in the ecosystem topic. Using culturally relevant learning contexts helped students connect scientific knowledge to local environmental practices. Ongoing reflection and instructional adjustments throughout the research cycles allowed the teacher to tailor strategies to students' needs. These findings support integrating local cultural practices into biology instruction to foster contextual, meaningful, and culturally responsive learning. However, the observed improvements should be considered within the scope of this classroom action research, as additional factors may have influenced students' achievement.

3.4 Discussion

This classroom action research (CAR) was conducted at SMA Negeri 1 Busang from March to May 2026 in response to initial findings of low learning outcomes among Grade XI students on the topic of ecosystems. Pre-test results showed that only three students scored above the Minimum Mastery Criterion (KKM) of 70, while most did not meet this standard. These findings suggest that students' mastery of ecosystem concepts is suboptimal and underscore the need to improve the learning process to make it more relevant and better aligned with students' characteristics.

An essential aspect of effective biology instruction is connecting subject matter to students' environments, experiences, and backgrounds. This approach ensures that concepts are not solely theoretical but are understood within contexts relevant to students' daily lives. To aTo address the identified issue, the Culturally Responsive Teaching (CRT) approach was implemented as an instructional intervention by linking ecosystem content to students' cultural contexts and experiences. This approach is intended to increase student engagement and support the development of contextual understanding, thereby improving biology learning outcomes related to ecosystems.

Culturally Responsive Teaching (CRT) aligns instructional strategies with students' cultural backgrounds to enhance learning relevance and effectiveness (Brown & Crippen, 2017). Through CRT, teachers are encouraged to use students' cultural experiences and immediate environments as meaningful learning resources, fostering emotional and cognitive connections between students and the subject matter (Comstock et al., 2023; D. Noviarini & Handayani, 2024; Whatoni et al., 2024). The CRT approach offers several advantages, including respecting students' cultural diversity (Muasaroh et al., 2026), making learning more relevant to students' daily lives (Muasaroh et al., 2026), and boosting student interest and learning outcomes (Whatoni et al., 2024).

A cultural practice closely associated with students' daily lives and suitable for implementing the Culturally Responsive Teaching (CRT) approach. Menugal is a traditional Dayak rice-planting practice that uses a simple wooden stick to create planting holes and emphasises community cooperation. In ecosystem studies, the Menugal practice can stimulate identification of biotic and abiotic components, interactions among living organisms, energy flow, and the relationship between humans and the environment. This approach lets students see how community activities use soil, plants, water, and other organisms as integral parts of an environmental system, moving beyond abstract ideas.

Findings from observations and evaluations during the pre-cycle stage informed the instructional planning for Cycle 1, which incorporated the Culturally Responsive Teaching (CRT) approach. The planning phase included developing teaching modules, guiding questions, instructional materials,

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student worksheets (LKPD), and assessment tools to measure Cycle 1 learning outcomes. As shown in Table 3, post-test results indicated that 14 students did not meet the mastery standard, while 11 students achieved mastery, resulting in a mastery rate of 44%. The average class score was 59.68. Although this score improved from the previous stage, it remained below the minimum mastery criterion (KKM) of 70.

Biology learning outcomes improved during Cycle 1, as shown by higher student scores and increased active participation throughout the learning process. Students demonstrated greater confidence in asking questions, sharing ideas, and presenting group worksheet results. These outcomes indicate that the Culturally Responsive Teaching (CRT) approach enhances student engagement by connecting subject matter to students' personal experiences, environments, and daily lives.

Observations and reflections from Cycle 1 informed the instructional design for Cycle 2, which placed greater emphasis on the Culturally Responsive Teaching (CRT) approach. The planning phase included preparing instructional materials and instruments, such as teaching modules, guiding questions, learning resources, and worksheets, tailored to students' characteristics and contexts. The team also developed assessment instruments to measure and evaluate student learning outcomes after implementing instruction in Cycle 2.

Data on the progression of mastery percentages across the pre-cycle, Cycle I, and Cycle II stages were obtained during the implementation of the Classroom Action Research (CAR). Comparing mastery percentages across these three stages indicates whether the intervention achieved its objectives and helps determine the overall success of the CAR implementation. Comparing results across stages allows us to observe changes and improvements in student mastery after implementing the instructional intervention. The comparison of mastery percentages from the pre-cycle, Cycle I, and Cycle II stages is presented in Figure 2.

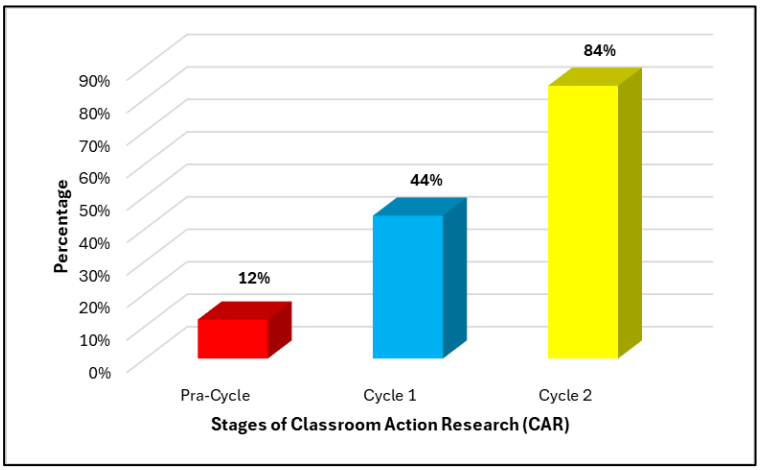

Figure 2. *Comparison of Grade Mastery Percentages*

Based on Figure 2, the percentage of students achieving mastery increased consistently across each stage of the classroom action research (CAR). In the pre-cycle stage, the mastery rate was only 12%; this rose to 44% in Cycle 1 and further increased to 84% in Cycle 2. These data indicate that the instructional interventions implemented in stages successfully improved student learning outcomes. The 32% increase from the pre-cycle to Cycle 1 reflects an initial change following the intervention. In comparison, the 40% increase from Cycle 1 to Cycle 2 shows that reflection-informed instructional improvements had a stronger impact on learning mastery. The 84% mastery rate in Cycle 2 indicates that most students met the established mastery criteria. These findings align with Rifqi et al. (2024), who explain that high mastery in Cycle 2 can indicate the success of the interventions or treatments applied during the learning process. Thus, the increase in mastery observed in this study represents not

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only a quantitative change but also an indicator of improvement in the learning process from one cycle to the next.

Research results indicate that implementing the Culturally Responsive Teaching (CRT) approach within a Classroom Action Research (CAR) framework led to increased student mastery of learning outcomes across successive cycles. The mastery rate rose from 12% in the pre-cycle stage to 44% in Cycle 1 and to 84% in Cycle 2. This improvement suggests that instruction that integrates students' cultures, experiences, and life environments fosters a more contextual, meaningful understanding of the material. Furthermore, reflection and action refinement in each cycle enabled the teacher to tailor instructional strategies to student needs. These findings show that CRT can enhance learning outcomes by making instruction relevant to students' backgrounds. Thus, CRT offers a viable alternative for improving instructional quality. However, the observed gains in mastery cannot be attributed solely to CRT without considering other factors that may also influence learning outcomes.

The improvement in learning outcomes is closely linked to the nature of Classroom Action Research, which positions reflection as the foundation for refining actions in subsequent cycles. In Cycle 1, the results of instruction and evaluation were used to identify areas requiring improvement, whether regarding teaching strategies, student engagement, or the management of the learning process. These reflections then informed the design of more appropriate actions for Cycle 2. Continuous improvement made instruction more focused and gave students more opportunities to grasp the material and improve their learning outcomes. Consequently, the rise in the mastery rate from 12% in the pre-cycle stage to 84% in Cycle 2 can be understood as the result of a systematic instructional improvement process involving the stages of planning, implementation, observation, and reflection. These findings show that intervention success in Classroom Action Research depends not only on applying a specific teaching method or strategy but also on the teacher's ability to evaluate the learning process and adjust actions based on students' needs in each cycle.

Based on the stages of the classroom action research that were carried out, a comparison of the scores for each cycle was obtained. Further details regarding the score comparison for each cycle are presented in Figure 3.

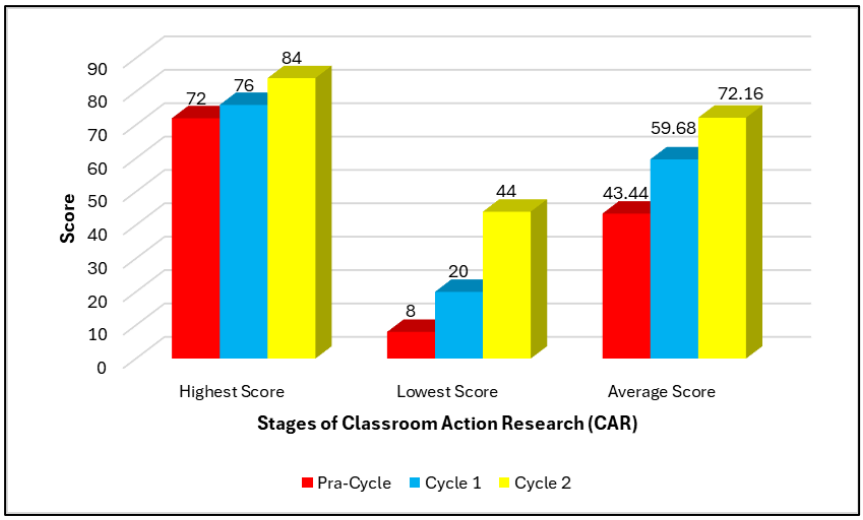

Figure 3. *Comparison of Learning Outcome Scores*

Figure 3 shows improvement in student learning outcomes at each stage of the classroom action research (CAR). The highest score increased from 72 in the pre-cycle stage to 76 in Cycle 1 and reached 84 in Cycle 2. Similarly, the lowest score rose from 8 in the pre-cycle stage to 20 in Cycle 1 and further to 44 in Cycle 2. The average student score also improved, progressing from 43.44 in the pre-cycle stage to 59.68 in Cycle 1 and 72.16 in Cycle 2. This trend suggests that implementing the Culturally Responsive Teaching (CRT) approach positively affects student learning outcomes, consistent with the

findings of Enjelina et al. (2024), Noviarini et al.(2024), and Whatoni et al. (2024). CRT helps connect learning materials to students' backgrounds, experiences, environments, and cultural contexts, improving the comprehensibility of the concepts being studied.

4. CONCLUSION

Based on these findings, students' Biology learning outcomes improved progressively across the implementation cycles of Culturally Responsive Teaching (CRT) integrated with the surrounding environment. The average learning score increased from 43.44 in the pre-cycle to 59.68 in Cycle I and 72.16 in Cycle II, while the proportion of students achieving mastery increased from 12% to 44% and 84%, respectively. These findings indicate that the implementation and continuous refinement of CRT-based learning were accompanied by improvements in students' learning outcomes. Integrating local culture, students' experiences, and their immediate environment into Biology instruction may provide more relevant and meaningful learning experiences. Furthermore, reflection and instructional adjustments across cycles enabled the teacher to refine learning strategies in response to students' learning needs. Although the findings suggest CRT-based learning can support improved Biology learning outcomes, the contribution of CRT cannot be isolated from other instructional changes introduced during the action-research process. Therefore, further research is needed to examine its effectiveness across different educational contexts and to investigate its influence on students' learning processes and outcomes.

AI USAGE STATEMENT

While preparing this manuscript, the authors used ChatGPT and Grammarly to refine language, paraphrase, and proofread. The authors carefully reviewed and revised all AI-assisted content and take full responsibility for the accuracy, originality, and academic integrity of the final published work.

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