



Problem-based biology learning with local biocultural issues for anticipatory competence

Alif Yanuar Zukmadini^{1*}, Fatchur Rohman², Murni Sapta Sari²

¹ Biology Education, Faculty of Teacher Training and Education, Universitas Bengkulu, Indonesia

² Biology Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia

*Corresponding author: ayzukmadini@unib.ac.id

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ABSTRACT

Problem-based Learning (PBL) is a common approach in science education. However, incorporating cultural and ecological contexts into PBL remains largely unexplored. This issue is particularly relevant for preparing pre-service teachers to address future environmental challenges, uncertainties, and potential solutions. This study examined whether problem-based learning (PBL) enriched with local biocultural issues could enhance anticipatory competence among pre-service biology teachers. A quasi-experimental two-group pre-test-post-test design was used, involving 45 fifth-semester students enrolled in an ethnobiology course at the University of Bengkulu. A census approach was employed, with one intact class assigned to the experimental group ($n = 24$) and the other to the control group ($n = 21$) for the intervention. Both groups followed the same general PBL structure for eight instructional sessions; however, the problem contexts differed. The control group addressed biodiversity problems mainly from ecological and conservation perspectives, whereas the experimental group engaged with local biocultural issues drawn from ethnozoological knowledge and conservation practices on Enggano Island. Anticipatory competence was assessed using six open-ended items covering current and future state analysis, uncertainty evaluation, and creative problem-solving dimensions. ANCOVA showed a significant difference between groups after adjusting for pre-test scores, $F = 7.76$, $p = .008$, partial $\eta^2 = .155$. The experimental group also achieved a higher adjusted post-test mean (79.86) than the control group (73.27), with stronger improvement across all three dimensions. These findings suggest that local biocultural enrichment can add meaningful contextual value to PBL and support future-oriented thinking in pre-service teacher-education.

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INTRODUCTION

Biology education prepares students to understand current and future environmental issues and develop appropriate solutions. This is particularly important in biodiversity and conservation education, where biodiversity loss and environmental change involve uncertainty, ecological and social risks, and long-term consequences (Aleknavičiūtė et al., 2023; Jeronen & Jeronen, 2026; Kopnina, 2020). Therefore, students need opportunities to interpret environmental changes, consider their possible consequences, and develop relevant responses to conservation challenges (Yang et al., 2024; Yli-Panula et al., 2023). In this context, anticipatory competence is particularly relevant because it involves the ability to consider possible futures, assess potential consequences, and explore alternative courses of action in sustainability-related situations (Ratinen & Linnanen, 2022; Sudarya et al., 2023).

In this study, anticipatory competence was operationalized through three interrelated dimensions: analysis of current and future conditions, evaluation of uncertainty, and creative problem-solving. The analysis of current and future conditions involves examining existing conditions and anticipating their evolution over time. The evaluation of uncertainty encompasses the recognition and assessment of uncertainties, risks, and potential consequences associated with possible future developments. Creative problem-solving involves formulating and considering alternative responses to anticipated sustainability challenges (Kioupi & Voulvoulis, 2022). Collectively, these dimensions represent the analytical, uncertainty-aware, and solution-oriented aspects of future thinking that are highly relevant to prospective biology teachers who will teach students about complex issues in biodiversity and conservation.

Developing anticipatory competence is crucial for preparing prospective biology teachers. As future educators, they will be responsible not only for teaching biological concepts but also for preparing students to face environmental and biodiversity challenges that may evolve over time (Liulenko et al., 2023). To fulfill this role, prospective biology teachers need the ability to analyze current conditions, anticipate future possibilities, recognize uncertainties and their potential consequences, and consider various alternative responses to environmental issues (Doychinova, 2024). Consequently, anticipatory competence serves as a key foundation for designing and facilitating learning experiences that encourage students to think beyond the present and consider diverse future scenarios (Suhendar et al., 2025). However, the development of this competence in prospective biology teacher education still requires further attention.

Developing such competencies requires learning contexts that connect biological issues with students' ecological and social realities, as meaningful learning is strengthened when students can relate what they learn to relevant real-life contexts (Andrews et al., 2023; Mróz & Ocetkiewicz, 2024). In this regard, local biodiversity issues provide an authentic context by confronting learners with the ecological and sociocultural challenges present in their immediate surroundings (Uskola & Puig, 2023). Knowledge of local organisms and ecological insights can also improve teachers' confidence in teaching biodiversity-related material (Id Babou et al., 2023). Biodiversity issues are often linked to community practices, customary rules, patterns of fauna utilization, intergenerational knowledge, and cultural values (Correia et al., 2026). These interconnections can be understood from a biocultural perspective, in which biodiversity and cultural practices are closely linked by the relationship between humans and the environment (Otamendi-Urroz et al., 2025; York, 2026). Such a context offers prospective teachers the opportunity to examine biodiversity issues as multidimensional matters involving ecological processes, human decisions, cultural practices and potential future consequences.

In this context, problem-based Learning (PBL) offers a pedagogical approach to developing anticipatory competence. PBL places meaningful problems at the core of learning, engaging students in exploring information, evaluating evidence, considering diverse perspectives, and formulating potential responses (Ningsih et al., 2025). Theoretically, these processes align with anticipatory competence, as they require learners to understand current conditions, navigate uncertainty, consider potential consequences, and evaluate alternative solutions (Bendeliani & Torstensdotter, 2026). The relevance of this approach is evident in biodiversity education, where local environmental issues often arise from the interplay between ecological processes and human practices (Iwan et al., 2024). This process also reflects the importance of making decision-making explicit, as evaluating alternative interventions requires learners to compare possible benefits, risks, and consequences (Benfield & Krueger, 2021).

Although the use of local knowledge in problem-based Learning (PBL) may help develop anticipatory competence, most previous studies on this competence have been conducted in the field of sustainability education (Brundiers et al., 2021; Goller & Rieckmann, 2022). Research on biodiversity

education has mainly focused on knowledge, attitudes, and environmental awareness (Umar et al., 2024). Meanwhile, studies on local and Indigenous knowledge in science education have generally focused on cultural relevance and contextual learning (Jannah et al., 2022). Although these studies have explored future-oriented competence, biodiversity education, and contextual learning, few have examined how these areas can be integrated into the education of future biology teachers. In particular, few studies have examined how local biocultural issues can be integrated into PBL to develop anticipatory competence among future biology teachers. This gap is important because the way a problem is presented can influence the direction and depth of students' reasoning during PBL (Bendeliani & Torstensdotter, 2026).

In this study, the local biocultural context is derived from ethnozoological knowledge and biodiversity conservation practices on Enggano Island. On the island, biodiversity is closely linked to community knowledge, animal use, cultural values, and the local community's relationship with animals (Zukmadini et al., 2024). Biodiversity issues on Enggano Island provide a relevant context for connecting biodiversity, culture, and conservation. This study utilizes these local biocultural issues as the problem context, rather than merely as examples of biodiversity. Through local biocultural issues, prospective biology teachers can learn biological topics alongside their social and cultural dimensions (Lukawiecki et al., 2022). This context also encourages them to consider how current practices might impact future biodiversity and what alternative actions could be taken.

Examining local biocultural issues as contextual enrichment within PBL, rather than comparing PBL with a fundamentally different instructional model. Accordingly, this study aimed to determine whether PBL enriched with local biocultural issues supports stronger anticipatory competence among pre-service biology teachers than PBL without such explicit enrichment. The study was guided by the following research question: Does PBL enriched with local biocultural issues foster greater anticipatory competence among pre-service biology teachers than PBL without local biocultural enrichment? Based on theoretical rationale and prior research, it was hypothesized that pre-service biology teachers who engaged in PBL enriched with local biocultural issues would exhibit higher anticipatory competence than those who engaged in PBL without such enrichment.

METHODS

Research Design

This study employed a quasi-experimental two-group pre-test-post-test design (Creswell & Creswell, 2018). The participants were assigned to a control group and an experimental group. Both groups received Problem-Based Learning (PBL), but with different problem contexts. The control group engaged in PBL using general biodiversity issues, whereas the experimental group engaged in PBL using biodiversity issues enriched with a local biocultural context. This design enabled an examination of the effect of contextual enrichment within PBL on the anticipatory competence of pre-service biology teachers.

Population and Samples

The study population comprised all fifth-semester undergraduate students in the Biology Education Study Program at Bengkulu University enrolled in the Ethnobiology course. A total population sampling (census sampling) technique was employed because the population was relatively small, allowing all eligible students to be included in the study. The participants came from two intact classes established prior to the study. In accordance with the quasi-experimental design, one intact class served as the experimental group ($n = 24$), while the other served as the control group ($n = 21$).

Instrument

The research instrument was first reviewed by experts and subsequently pilot-tested with prospective biology teachers before being used in the main study. Expert validation was conducted by three experts in biology education, educational assessment, and environmental education. These experts evaluated the suitability of the content, the relevance of each item to the measured construct, and the linguistic clarity. The expert validation results yielded an average Aiken's V of 0.86, indicating that the instrument possessed adequate content validity. After that, conducted empirical validation with 35 seventh-semester prospective biology teachers who were not involved in the main study. The analysis results showed that the Pearson item-total correlation values ranged from 0.612 to 0.725 (Table 1). These values indicate that all six items demonstrated adequate correlation with the instrument's total score. The reliability analysis yielded a Cronbach's α value of 0.749, indicating acceptable internal consistency. Thus, the results of expert validation, empirical item analysis, and reliability testing

demonstrate that the instrument is suitable for measuring anticipatory competence in the main study. The original assessment items were open-ended questions developed based on relatively lengthy contextual scenarios. Therefore, Table 1 presents a summary of each item to measure the three dimensions of anticipatory competence.

Table 1.
Test Items to Measure Anticipation Competence

Dimensions	Item	Questions	Pearson Item-Total Correlation
Current and Future States Analysis	1	How might the use of animals in traditional practices affect future conservation of local animal populations?	0.612
	2	What ecological, social, cultural, and economic consequences might arise if the use of animals in traditional practices changes or declines?	0.725
Creative Problem-Solving	3	What alternative solutions can preserve the cultural value of animal use while simultaneously supporting biodiversity conservation and sustainability?	0.645
	6	How can phased, long-term strategies be developed to preserve traditional practices involving animals while protecting biodiversity for future generations	0.661
Uncertainty Evaluation	4	What unintended consequences might emerge from the proposed solutions aimed at balancing traditional animal use with biodiversity conservation?	0.700
	5	What uncertainties and risks might arise from interventions designed to ensure the conservation of animal populations used in traditional practices, and how can these risks be minimized?	0.696

Procedure

Before the intervention, students in both groups completed the same pre-test to assess their initial anticipatory competence. Both groups followed the same five phases of problem-based Learning: (1) problem orientation, (2) organizing students for learning, (3) guiding investigation, (4) developing and presenting solutions, and (5) reflection and evaluation. The main difference between the groups was the context of the problems used throughout these phases. The control group engaged with biodiversity issues approached primarily from ecological and conservation perspectives, including species diversity, ecological relationships, habitat disturbance, biodiversity threats, and species conservation. In contrast, the experimental group engaged with local biocultural issues derived from ethnozoological knowledge and biodiversity conservation practices on Enggano Island. These issues incorporated local knowledge, customary practices, cultural values, human-fauna relationships, and conservation concerns into the PBL process. The implementation of the five PBL phases and the main differences between the experimental and control groups are summarized in Figure 1.

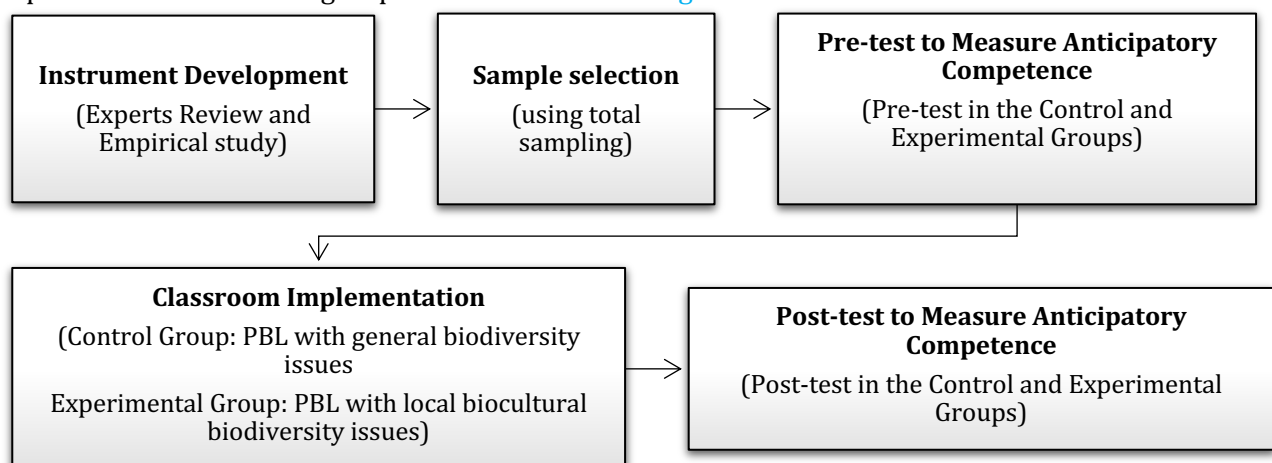


Figure 1. Research Procedure and Comparison of PBL Implementation in the Experimental and Control Groups

The implementation of biodiversity learning through PBL enriched with local biocultural issues was not limited to content delivery alone but was realized through an integrated instructional design consisting of learning objectives, locally grounded case-based teaching materials, authentic problem scenarios, contextual media, investigative worksheets, instructional syntax, and assessment tools designed to measure students' anticipatory competence. To clarify how this approach was operationalized in the learning process, the main components of the instructional designs are listed in [Table 2](#).

Table 2.

Components of Biodiversity Learning through Problem-Based Learning with Local Biocultural Issues.

Component	Function in Learning	Experimental Group: PBL with Local Biocultural Issues	Control Group: PBL with General Biodiversity Issues
Learning objectives	Direct learning toward understanding biodiversity and developing anticipatory competence	Analyzed the current biodiversity issues on Enggano Island, anticipated future environmental changes, evaluated uncertainties, and proposed sustainable solutions to address these issues.	Analyze biodiversity issues primarily from ecological and conservation perspectives without explicit local biocultural enrichment, anticipate possible environmental changes, evaluate uncertainties and propose sustainable solutions.
Learning content	Provide scientific and contextual knowledge about Biodiversity concepts	Biodiversity concepts are integrated with Enggano fauna, traditional ecological knowledge, customary practices, local cultural values, and biodiversity conservation issues.	Biodiversity concepts focus on species diversity, ecological relationships, threats to biodiversity, habitat change, and conservation, without explicit integration of local biocultural knowledge.
Teaching materials	Present biodiversity issues as the primary learning resources	Textbook based on the ethnozoological knowledge of the Enggano community and local biodiversity conservation challenges.	Textbook presented biodiversity and conservation problems from general ecological perspectives.
Problem scenarios	Authentic and complex problems should be provided as triggers for collaborative inquiry.	Cases involving the utilization of Enggano fauna, declining traditional ecological knowledge, changes in customary practices, human-wildlife interactions, and biodiversity conservation challenges were included.	Cases involving biodiversity decline, habitat disturbance, species conservation, ecological pressures, and other biodiversity problems without explicit local biocultural framing.
Learning media	Visualizing biodiversity issues to strengthen contextual understanding.	Photographs and videos of Enggano wildlife, habitat maps, interview excerpts with local community members, and documentation of customary practices.	Photographs, videos, diagrams, and maps illustrating biodiversity, habitats, ecological threats, and conservation issues are included.
Student worksheets	Students are guided through systematic inquiry and collaborative problem solving.	Worksheets for identifying biodiversity problems on Enggano Island, analyzing future scenarios, evaluating alternative solutions, and developing sustainability-oriented action plans.	Worksheets guided students to identify biodiversity problems, analyze possible future conditions, evaluate alternative solutions, and develop conservation-oriented responses based on ecological information.
PBL learning activities	Organize collaborative inquiry through the stages of Problem-Based Learning.	Problem orientation, group investigation, analysis of Enggano ethnozoological cases, presentation of proposed solutions and reflective discussion.	Problem orientation, group investigation, analysis of biodiversity, conservation cases without explicit local biocultural enrichment, presentation of solutions, and reflective discussion.
Assessment instruments	Assess students' anticipatory competence	Essay tests	Essay tests

Data Analysis Techniques

Post-test scores for anticipatory competence were analyzed using a one-way ANCOVA, with pre-test scores as the covariate. The effect size was reported as partial eta squared (η^2). Following Cohen's (1988), values of 0.01, 0.06, and 0.14 were interpreted as small, medium, and large effects, respectively. The analysis examined the difference in post-test scores between the control and experimental groups after controlling for students' initial abilities. Prior to the analysis, the assumptions of ANCOVA, including normality of residuals, homogeneity of variance, linearity between the covariate and dependent variables, and homogeneity of regression slopes were examined.

RESULTS AND DISCUSSION

The descriptive results showed higher improvement in anticipatory competence in the experimental group than in the control group after the intervention. To examine whether this difference remained after controlling for students' initial anticipatory competence, a one-way ANCOVA was conducted using the pre-test scores as a covariate. Prior to ANCOVA, the assumptions of normality, homogeneity of variance, linearity, and homogeneity of regression slopes were examined and found to be met. The results of the ANCOVA are shown in Table 3.

Table 3.

ANCOVA Results for Anticipatory Competence with Pre-test as a Covariate.

Source	Df	F	P	Partial η^2	Effect Size
Pre-test (Covariate)	1	39.40	0.001	0.484	Large
Group	1	7.76	0.008	0.155	Large

The ANCOVA results showed that pre-test scores were significantly related to post-test anticipatory competence ($p = .001$). After controlling for pre-test scores, the difference between the experimental and control groups remained significant, $F = 7.76$, $p = .008$, partial $\eta^2 = .155$. This indicates a large, adjusted group effect. Table 4 presents the pre-test and post-test means, mean differences, percentage increases, and adjusted post-test means to show the extent of change in each group.

Table 4.

Descriptive Statistics and Adjusted Post-test Means of Anticipatory Competence in the Experimental and Control Groups.

Group	Pre-test Mean	SD	Post-test Mean	SD	Mean Difference	Percentage Increase	Adjusted Post-test Mean (SE)
Experimental	59.95	14.46	79.62	9.91	19.68	33%	79.86 (1.62)
Control	60.84	11.97	73.54	12.03	12.70	21%	73.27 (1.73)

As shown in Table 4, both groups improved, but the experimental group showed a higher gain than the control group (19.68 points compared with 12.70 points). After controlling for pre-test scores, the experimental group also achieved a higher adjusted post-test mean (79.86) than the control group (73.27). These results suggest that both groups are influenced by PBL, but local biocultural enrichment was associated with a stronger improvement in anticipatory competence. The experimental group showed higher improvement when PBL was enriched with local biocultural biodiversity issues than the control group. This difference is meaningful because both groups followed the same general PBL structure, but the problems they worked on were not equally rich in context. In the control group, biodiversity issues were discussed mainly from an ecological and conservation perspective. In the experimental group, these issues were also connected with local knowledge, customary practices, cultural values, human-fauna relationships, and local conservation challenges. This broader context may have made the problems more authentic and complex, requiring students to consider present conditions, possible future consequences, uncertainty, and different response options. This is consistent with (Redman & Wiek, 2021) who described anticipatory competence as the ability to think about possible futures, deal with uncertainty, and consider the consequences of alternative actions in sustainability-related situations. Therefore, the stronger performance of the experimental group appears to reflect the added value of local biocultural enrichment within PBL, rather than the effect of PBL alone. This becomes clearer when the learning process is examined across the five phases of PBL:

In the problem orientation phase, both groups worked with biodiversity problems, but the focus of these problems differed. The control group mainly examined species diversity, ecological

relationships, habitat disturbance, biodiversity threats, and conservation. In the experimental group, these problem scenarios were also linked to Enggano fauna, traditional ecological knowledge, customary practices, cultural values, and human-fauna relationships. This broader context encouraged students to see biodiversity not only as an ecological issue but also as a problem connected to culture and community life. This is in line with Lasekan et al. (2023), who showed that learning based on local cultural issues can help students anticipate future challenges. Ghazali et al. (2024) also found that authentic sustainability contexts can support learning for sustainable development, while Kleespies and Dierkes (2022) emphasized the value of examining biodiversity from multiple perspectives.

During the organizing-students-for-learning phase, students in both groups identified the main problems, discussed the available information, and planned further investigation. In the control group, the discussion focused mainly on ecological and conservation information. In the experimental group, students also considered local knowledge, community practices, cultural meanings, and conservation concerns. This wider range of information encouraged students to look beyond biological explanations and consider how different stakeholders might understand the same biodiversity issue in different ways. They also had to think about how different decisions could lead to different future consequences. This is in line with Xu et al. (2023), who emphasized that classroom discussion can strengthen critical analysis and the evaluation of different viewpoints. It also supported by Kelley and Dietl (2022), who highlighted the importance of evaluative reasoning when students work with complex problems.

The difference between the two groups became clearer during the guiding investigation phase. Students in the experimental group explored local biocultural information through contextual teaching materials, learning media and other sources related to Enggano biodiversity and local communities. These activities helped them understand fauna not only as biological organisms but also as part of local livelihoods, knowledge systems, customary practices, and conservation efforts. In contrast, the control group investigated biodiversity problems primarily through ecological and conservation information, without explicit local biocultural enrichment. Both approaches can support problem-solving, but the experimental group worked with a broader, more complex range of information than the control group. This interpretation is supported by Id Babou et al. (2023), who emphasized that biodiversity is understood through complex relationships and both biocentric and anthropocentric perspectives, highlighting the importance of addressing biodiversity in ways that reflect its multidimensional nature.

During the solution development and presentation phase, students in both groups were asked to propose and communicate solutions to the problems they investigated. Students in the control group primarily drew on ecological and conservation perspectives, whereas those in the experimental group also considered local knowledge, cultural practices, community interests, and sustainability. This broader scope of considerations required students to compare various options before deciding on their course of action. This process aligns with the importance of making decision-making explicit, given that evaluating alternative interventions involves weighing potential benefits, risks, and consequences (Benfield & Krueger, 2021). It also aligns with Wilkerson (2025), who emphasized the need to integrate diverse perspectives when addressing sustainability-related issues. Thus, integrating biocultural perspectives in the experimental group provided a broader foundation for students to evaluate potential solutions and consider their implications.

Finally, in the reflection and evaluation phase, both groups reviewed their problem-solving processes and proposed solutions; however, the scope of reflection differed. The control group focused mainly on biodiversity problems, conservation responses, and their ecological implications. The experimental group also considered how proposed solutions might affect local knowledge, cultural practices, community relationships with fauna, and future sustainability. Reflection therefore went beyond asking whether a solution could address an ecological problem and also considered whether it would remain appropriate under changing ecological and sociocultural conditions. This is consistent with Bendeliani & Torstensdotter (2026), who suggested that reflective processes in PBL can strengthen students' ability to analyze, evaluate, and respond to future challenges.

Local biocultural enrichment did not change the basic PBL structure, but it broadened the issues students needed to analyze, perspectives they had to consider, consequences they had to anticipate, and range of solutions they needed to evaluate. This broader learning context may help explain the stronger improvements observed in the control and experimental group for three dimensions of anticipatory competence. The changes in these three dimensions are shown in Figure 2.

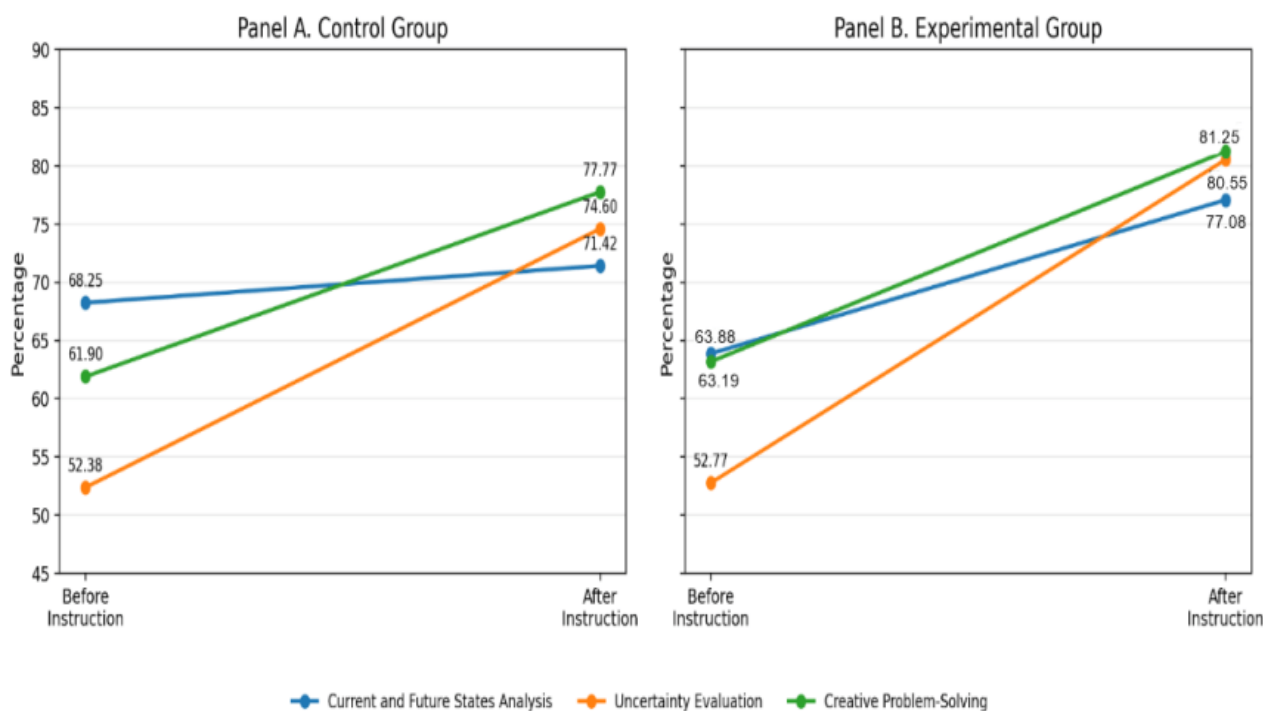


Figure 2. Changes in Anticipatory Competence Dimensions Before and After Instruction.

Figure 2 shows that the experimental group improved more strongly across all three dimensions. The largest difference in improvement was observed in the current and future states analysis, with the experimental group increasing by 13.20 points compared with 3.17 points in the control group. Uncertainty evaluation increased by 27.78 and 22.22 points, respectively, while creative problem-solving increased by 18.06 and 15.87 points. These patterns suggest that local biocultural enrichment supported broader development across the three dimensions, although the dimension-level results are interpreted descriptively. Overall, these results show that local biocultural enrichment within PBL was associated with stronger development across all three dimensions of anticipatory competence, particularly in dealing with uncertainty and in developing future-oriented responses.

The greater improvement in the uncertainty evaluation dimension may be related to the types of problems students encountered. The control group worked mainly on biodiversity threats, ecological relationships, habitat changes, and conservation issues. These problems still required reasoning and contributed to improvement. However, the experimental group also had to consider community practices, cultural values, local knowledge, patterns of fauna use, and conservation needs. This made the problems less straightforward and required students to weigh different interests, risks, and possible consequences. This interpretation is consistent with Kioupi & Voulvoulis (2022), who identified uncertainty and alternative future scenarios as important components of anticipatory competence. It is also in line with Ratinen & Linnanen (2022) who emphasized the importance of reasoning under uncertainty in sustainability-oriented learning.

A similar pattern was observed in the dimension of creative problem-solving. Both groups improved because PBL required students to develop responses to biodiversity problems. However, students in the experimental group had to consider not only ecological and conservation aspects but also local knowledge, customary practices, cultural values, and human-fauna relationships. Bringing these different considerations together may have encouraged them to generate and compare a wider range of possible solutions. This finding is consistent with Ee et al. (2023), who emphasized that creative responses are closely connected to analytical and evaluative abilities. The results for the current and future state analysis dimension also support this pattern. The experimental group began with a lower score of 63.88 than the control group at 68.25. After instruction, however, the experimental group reached 77.08, while the control group reached 71.42. This suggests that local biocultural enrichment may have helped students connect current biodiversity conditions to potential ecological and sociocultural consequences in the future. This is in line with Mróz and Ocetkiewicz (2024), who

emphasized that anticipatory thinking requires learners to understand current conditions and consider how those conditions may change over time.

Overall, the stronger post-instruction performance of the experimental group was reflected not only in the total score but also across all three dimensions of anticipatory competence. This suggests that the intervention supported broader development rather than improvement in only one specific aspect. By integrating local knowledge, cultural practices, human-fauna relationships, and sustainability concerns into problem analysis, inquiry, solution development, and reflection, the experimental learning environment gave students a richer context for thinking about possible futures, uncertainty, and alternative responses. This is consistent with Hemming et al. (2022) and Franco (2022), who emphasized that biodiversity learning becomes more meaningful when it is connected with lived experiences, community needs, and cultural practices. Méndez-Herranz and Cabello (2025) also argued that local biocultural contexts can help pre-service teachers understand biodiversity as part of broader sustainability responsibilities. Garavito-Bermúdez (2020) similarly highlighted the importance of understanding biodiversity through relationships among species, humans, and culture. In the same direction, Fuentes-Vilagrón et al. (2026) and Lukawiecki et al. (2022) support the view that local and traditional knowledge should be treated as part of a holistic learning process, rather than as additional ecological information. In this study, this integration appears to have broadened students' understanding of biodiversity problems and supported stronger development across the three dimensions of anticipatory competence.

These findings suggest that biodiversity learning does not focus on ecological concepts and conservation knowledge. Integrating local knowledge, cultural practices, and human-fauna relationships into PBL can provide pre-service biology teachers with richer opportunities to connect biological concepts with uncertainty, future consequences, and alternative conservation responses. This approach may help prepare future biology teachers to design learning experiences that are more contextual, culturally relevant, and future oriented.

CONCLUSION

This study shows that Problem-Based Biology Learning enriched with local biocultural issues supported stronger development of anticipatory competence among pre-service biology teachers than PBL without explicit local biocultural enrichment. The improvement was reflected in the dimensions of current- and future-state analyses, uncertainty evaluation, and creative problem-solving, suggesting that local biocultural issues can provide a richer context for students to consider future consequences, uncertainty, and alternative responses to biodiversity problems. These findings support integrating local knowledge, cultural practices, human-fauna relationships, and conservation concerns into PBL to promote more contextual and future-oriented biology learning. However, the proposed contribution of the five PBL phases should be interpreted cautiously because process-level evidence was not directly examined in this study. Given the relatively small sample size, limited intervention period, and focus on a single biocultural setting, future studies should examine this approach with larger and more diverse samples, longer interventions, and different biocultural contexts.

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