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Development of a Learning Module Based on the Modified Free Inquiry Approach to Develop University Students' Critical Thinking Skills

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Critical thinking is a key learning outcome in higher education, requiring logical, reflective, and productive reasoning for decision-making. This study aims to train and evaluate students' critical thinking skills through the implementation of a teaching module based on a modified inquiry approach (free modified inquiry). The research employed a one-group pretest–posttest design with 37 first-semester students in the Biology Science Education program. Data were collected using a critical thinking test and analyzed quantitatively and descriptively using N-Gain indicators at both the individual level and for each skill indicator. The results show that the modified inquiry–based module effectively fosters critical thinking skills; N-Gain scores ranged from moderate to high categories, with the average improvement falling in the moderate category consistently across indicators. This improvement is associated with students' active involvement in planning and organizing the learning process. The findings indicate that the free modified inquiry model is suitable for training critical thinking skills on the topic of membrane transport and has the potential for broader adoption to strengthen andragogical learning practices that position students as active subjects in learning.

Keywords: Critical Thinking; Free Modified Inquiry; Modified Inquiry Approach; Teaching Modul

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INTRODUCTION

Natural science is a field of knowledge that can be used to assess and cultivate various thinking skills. Science is not merely a set of facts, concepts, and theories to be memorized; it also comprises active activities and processes that employ scientific reasoning and attitudes to understand living organisms and their interactions (Hadi et al., 2018).

One branch of natural science is biology. Understanding biology requires specific approaches such as observation, experimentation, drawing conclusions, and constructing theories that are interrelated (Loison, 2024). Biology instruction should enhance thinking skills, including higher-order thinking such as critical thinking. Students learn not merely to recall facts but to discern the phenomena behind those facts, enabling them to connect words and ideas (Muñoz Tabares, 2025). Dechaume et al. recommend convergent learning, which is often associated with critical thinking, logical reasoning, and problem-solving tasks that require selecting the most appropriate solution from a set of possibilities (Dechaume et al., 2024).

Critical thinking is reasonable thinking about what to believe and what to do (Ennis, 2018). It is a core competency in higher education, enabling students to make well-reasoned decisions, solve complex problems, and evaluate diverse forms of information (Salido et al., 2025). The success of a learning process is reflected in meeting three essential criteria: knowledge, attitudes, and skills. Cultivating critical thinking skills cannot be accomplished in a single session; it must be developed gradually and continuously so that students become accustomed to solving problems through critical reasoning. Therefore, the participants in this study were first semester students in the Biology Science Education program at UIN Mataram who were enrolled in the Basic Biology course. This view is supported by (Huber and Kuncel, 2016), who reported that critical thinking skills increase significantly over the course of higher education, indicating that sustained practice is necessary to achieve substantial gains (Huber & Kuncel, 2016).

Learning activities should be designed to guide students in developing attitudes, knowledge, and critical thinking skills, with varying combinations and emphases (Ibrahim, 2008). The cultivation of critical thinking with differing emphases can be operationalized through several indicators targeted within the learning process. The indicators selected for this study are: (1) making decisions to design experimental steps for problem solving, (2) conducting analysis, (3) drawing inferences, (4) performing evaluation, and (5) formulating conclusions. These indicators were adapted from (Ennis, 1996). Efforts to foster students' critical thinking can be implemented through student-centered learning models that allow learners to construct their own knowledge and learn in ways that match their preferred styles. One such student-centered model is the Modified Free Inquiry approach (Eristya & Aznam, 2019).

The inquiry-based learning model is used as an alternative to improve conventional methods that still emphasize the content transmission paradigm, in which information is transferred from teachers to students. The inquiry model shifts instruction from teacher-centered to student-centered by actively engaging students in the teaching–learning process (Asna, 2014). It is employed to develop university students' critical thinking skills because its instructional steps (syntax) align with the critical thinking indicators specified in this study.

In inquiry-based learning, several levels can be implemented, including guided inquiry, modified free inquiry, and free inquiry. Previous studies in biology education have generally focused more on the use of guided inquiry or free inquiry models. Guided inquiry provides structured direction, but it may limit students' independence in making scientific decisions. Conversely, free inquiry offers greater autonomy, but it may not be fully appropriate for first-semester students who still require guidance in understanding concepts, designing experiments, and drawing conclusions. Therefore, this study applies the Modified Free Inquiry model as its novelty, as this model is positioned between guided inquiry and free inquiry. Through this model, students are given opportunities to independently design experimental procedures, analyze data, evaluate results, and formulate conclusions, while still receiving limited guidance from the lecturer when necessary. Thus, Modified Free Inquiry is considered more appropriate for the cognitive level of first-semester students in the Biology Education Study Program and is expected to serve as a more adaptive approach to developing critical thinking skills in the Basic Biology course.

Observations conducted in the first-semester Biology Science Education classes at UIN Mataram indicate that students remain largely passive during instruction. They tend to sit quietly and only listen to the lecturer's explanations, which leads them to follow the lecturer's sequence and rely on memorization of the material, making it difficult to cultivate critical thinking skills. Interviews with the instructor of the Basic Biology course yielded similar findings. The current instructional materials still rely on the lecture method, supplemented with individual or group assignments. An analysis of the most recent Semester Learning Plan used in the Basic Biology course likewise shows a predominance of lecturing. Such an approach is ill-suited for developing students' critical thinking skills. Instruction that requires experimental activities generally needs supporting materials, such as a well-designed module, to effectively foster critical thinking.

METHOD

This study employed a pre-experimental design with a one-group pretest–posttest format. The participants were 37 first-semester students in the Biology Science Education program at UIN Mataram who were enrolled in the Basic Biology course. The research was conducted over four weeks, from 1 to 30 September 2025. The learning materials used to develop students' critical thinking skills were developed by the researchers. Specifically, a Modified Free Inquiry–based instructional package was implemented for the topic of substance transport across cell membranes. The instructional materials had previously undergone a validity assessment and were deemed valid.

The instructional package was developed through several stages, namely needs analysis, formulation of learning objectives, preparation of teaching materials and student worksheets, expert validation, revision, and classroom implementation. The validation process involved experts in biology education and learning evaluation who assessed the relevance, content accuracy, language clarity, construct suitability, and alignment of the materials with the Modified Free Inquiry model and critical thinking indicators. Each component was assessed using a structured validation rubric with a Likert-type scale, ranging from very poor to very good. The validation results were used as the basis for revising the materials before they were implemented in the learning process.

The essay test instrument was also validated before use to ensure that each item was aligned with the intended critical thinking indicators. The scoring of students' answers was conducted using an analytic rubric that assessed the quality of reasoning, accuracy of concepts, clarity of explanation, and ability to draw logical conclusions. Instrument reliability was examined to determine the consistency of the scoring results. Thus, the validity and reliability procedures were conducted to ensure that both the instructional materials and the assessment instrument were appropriate for measuring students' critical thinking skills.

The instrument used to measure students' critical thinking skills was a constructed response (essay-type) test consisting of five items to assess the indicators specified in this study. The test was found to be sensitive in distinguishing students' abilities before and after instruction, with a positive sensitivity index ranging from 0.52 to 0.68. It was administered in two phases—pretest and posttest—to determine students' critical thinking skills before and after the learning process.

The teaching–learning process comprised four meetings, each supported by a student worksheet for the topic under discussion. The worksheets were designed based on the Modified Free Inquiry model, resulting in a greater proportion of student involvement during instruction. The steps to be completed in the worksheets included problem orientation, problem formulation, hypothesis formulation, identifying and defining variables, designing procedures, analyzing data, making inferences, evaluating, and drawing conclusions. Through these steps, students were able to develop their critical thinking skills.

The students' critical thinking scores obtained from the tests were then categorized according to each student's critical thinking level. The levels comprised four criteria: >25.00–≤43.75 (very low critical), >43.75–≤62.50 (low critical), <62.50–≤81.25 (critical), and >81.25–≤1.00 (very high critical) (Supriyati et al., 2018).

The change or improvement in students' critical thinking test scores was analyzed using the N-Gain equation (Hake, 1999).

$$N - Gain = \frac{Posttest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score}$$

The N-Gain values for students' critical thinking skills can be interpreted using the following criteria: high greater than 0.70, medium 0.30 to 0.70, and low less than 0.30.

The analyses of students' critical thinking levels and their N-Gain improvements were used to determine whether the developed instructional materials were effective for fostering students' critical thinking skills

RESULT AND DISCUSSION

Students' Critical Thinking Skills Test Scores

Students' critical thinking skills were measured using an essay-type test instrument. The test scores are presented in Table 1.

[Table 1 about here.]

Based on the data presented in Table 1, the pretest results show that none of the students met the Minimum Mastery Criterion (KKM) set by UIN Mataram, which is 60. In the posttest, 33 students met the criterion and 4 students did not. The failure of these four students was attributable to several factors, including unproductive activity, insufficient concept mastery, divided attention due to factors outside the classroom, and decreased learning motivation. Students' intention or motivation to learn can shape their learning attitudes, including their engagement in productive tasks during instruction (Yu et al., 2025). Overall, the class achieved a mastery rate of 89.2%. The N-Gain analysis of improvements in critical thinking skills indicated that 18.9% of students fell into the high category, 70.3% into the medium category, and 10.8% into the low category.

Conceptual understanding is crucial for improving students' critical thinking skills. Inadequate mastery of concepts was one of the reasons why students coded A3, A4, A10, and A16 did not meet the mastery criterion and fell into the low to very low critical thinking categories. Their lack of conceptual mastery was evident on the multiple-choice test designed to measure conceptual understanding. Students A3, A4, A10, and A16, respectively, obtained scores that were classified as not meeting the criterion. This lack of conceptual mastery is illustrated in Figure 1. Difficulties in understanding concepts can impair students' ability to analyze problems critically. Hashemi et al reported that conceptual understanding is a key factor in learning topics such as derivatives in calculus (Hashemi et al., 2014).

[Figure 1 about here.]

Mastery of Critical Thinking Skill Indicators

The indicators of students' critical thinking skills in this study comprised formulating experimental procedures, analyzing, drawing inferences, evaluating, and formulating conclusions. The mastery of these indicators is presented in Table 2.

[Table 2 about here.]

Based on the N-Gain analysis of critical thinking score improvements presented in Table 2, none of the indicators met the mastery criterion at the pretest stage, whereas all indicators met the criterion at the posttest stage. The N-Gain values for each indicator ranged from 0.5 to 0.7, falling within the medium to high categories. These results indicate that instruction using the Modified Free Inquiry model is effective for developing students' critical thinking skills. This finding is consistent with Mardani et al., who reported that the success of this learning model in enhancing critical thinking stems from students' active involvement in organizing the learning process (Mardani et al., 2021).

The differences in improvement across indicators suggest that each component of critical thinking requires different cognitive demands. Indicators such as formulating conclusions, evaluation, and inference showed relatively stronger improvement because these skills were directly supported by the learning stages in the Modified Free Inquiry model. During the learning process, students were encouraged to observe problems, test ideas through experimental activities, compare findings, and draw conclusions based on the evidence obtained. These activities provided repeated opportunities for students to connect experimental results with biological concepts, making these indicators easier to develop within the learning sequence. In contrast, the analyzing indicator showed the lowest improvement. This may be because analysis requires more complex cognitive processing than identifying information or drawing conclusions from observable results. In the context of biology learning, analysis requires students to break down information, identify relationships among concepts, interpret data, distinguish relevant and irrelevant evidence, and construct logical explanations. Many students were still able to understand the basic concepts and answer the questions, but they had difficulty organizing their ideas into systematic analytical explanations. This indicates that their conceptual understanding had begun to develop, but their ability to express deeper reasoning in structured written form was still limited (Mudaningrat et al., 2022).

Students' difficulties in the analyzing indicator may also be related to their status as first-semester students. At this stage, students are still adapting to higher education learning patterns, particularly learning activities that require independent reasoning, scientific argumentation, and written explanation. Although the Modified Free Inquiry model provides opportunities for students to design procedures, analyze findings, and evaluate results, the development of analytical thinking generally requires longer and more intensive practice. Therefore, the lower improvement in the analyzing indicator does not necessarily indicate that the model was ineffective, but rather that analytical thinking is a higher-level skill that develops more gradually than other indicators (Henrliniar, 2022).

These findings imply that the implementation of Modified Free Inquiry should be strengthened by providing more explicit scaffolding in the analysis stage. Lecturers may guide students through analytical questions, data interpretation exercises, comparison of evidence, and structured scientific writing tasks (Sorte et al., 2020). Such support can help students move beyond surface-level responses and develop the ability to explain relationships among concepts, evidence, and conclusions more logically. Thus, while the Modified Free Inquiry model was effective in improving students' overall critical thinking skills, further refinement is needed to optimize students' analytical ability.

CONCLUSION

Based on the findings of this study, a learning module based on the Modified Free Inquiry Approach has the potential to improve students' critical thinking skills on the topic of mobile transportation. This potential is evidenced by the increase in N-Gain scores both at the individual student level and across all assessment indicators. The analysis also revealed a positive correlation between critical thinking skills and conceptual understanding, such that improvements in one tend to be accompanied by improvements in the other. These results support the use of this approach for similar topics in higher education and highlight opportunities for further research to assess its long-term effects and compare it with alternative learning models.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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TABLE 1 / N-Gain Analysis Results for Students' Critical Thinking Skills

Students	Score		Crit.	*N-Gain*	Crit.
	Pretest	*Posttest*			
A1	20,0	75,0	C	0,7	Midle
A2	45,0	95,0	VC	0,9	Hight
A3	30,0	47,0	LC	0,2	Low
A4	10,0	30,0	VLC	0,2	Low
A5	0,0	65,0	C	0,7	Midle
A6	0,0	75,0	C	0,8	Hight
A7	30,0	80,0	C	0,7	Midle
A8	25,0	65,0	C	0,5	Midle
A9	10,0	65,0	C	0,6	Midle
A10	10,0	30,0	VLC	0,2	Low
A11	25,0	75,0	C	0,7	Midle
A12	25,0	65,0	C	0,5	Midle
A13	25,0	75,0	C	0,7	Midle
A14	10,0	70,0	C	0,7	Midle
A15	10,0	65,0	C	0,6	Midle
A16	0,0	20,0	VLC	0,2	Low
A17	0,0	65,0	C	0,7	Midle
A18	15,0	95,0	VC	0,9	Hight
A19	35,0	85,0	VC	0,8	Hight
A20	15,0	65,0	C	0,6	Midle
A21	25,0	65,0	C	0,5	Midle
A22	0,0	65,0	C	0,7	Midle
A23	25,0	85,0	VC	0,8	Hight
A24	25,0	85,0	VC	0,8	Hight
A25	65,0	90,0	VC	0,7	Midle
A26	15,0	65,0	C	0,6	Midle
A27	10,0	65,0	C	0,6	Midle
A28	5,0	70,0	C	0,7	Midle
A29	25,0	70,0	C	0,6	Midle
A30	0,0	80,0	C	0,8	Hight
A31	25,0	65,0	C	0,5	Midle
A32	25,0	65,0	C	0,5	Midle
A33	25,0	65,0	C	0,5	Midle
A34	0,0	65,0	C	0,7	Midle
A35	35,0	70,0	C	0,5	Midle
A36	25,0	65,0	C	0,5	Midle
A37	35,0	70,0	C	0,5	Midle

VLC (Very Less Critical); LC (Less Critical); C (Critical); and VC (Very Critical).

TABLE 2 / Mastery of Indicators and N-Gain Analysis of Critical Thinking Skills

Indicator	Score Proportion		Criteria	*N-Gain*	Criteria
	Pret.	*Post.*			
Formulating experimental procedures	22,3	70,3	Passed	0,6	Midle
Analyzing	20,9	64,2	Passed	0,5	Midle
Drawing inferences	14,9	62,8	Passed	0,6	Midle
Evaluating	21,6	75,9	Passed	0,7	Hight
Formulating	15,5	66,2	Passed	0,6	Midle

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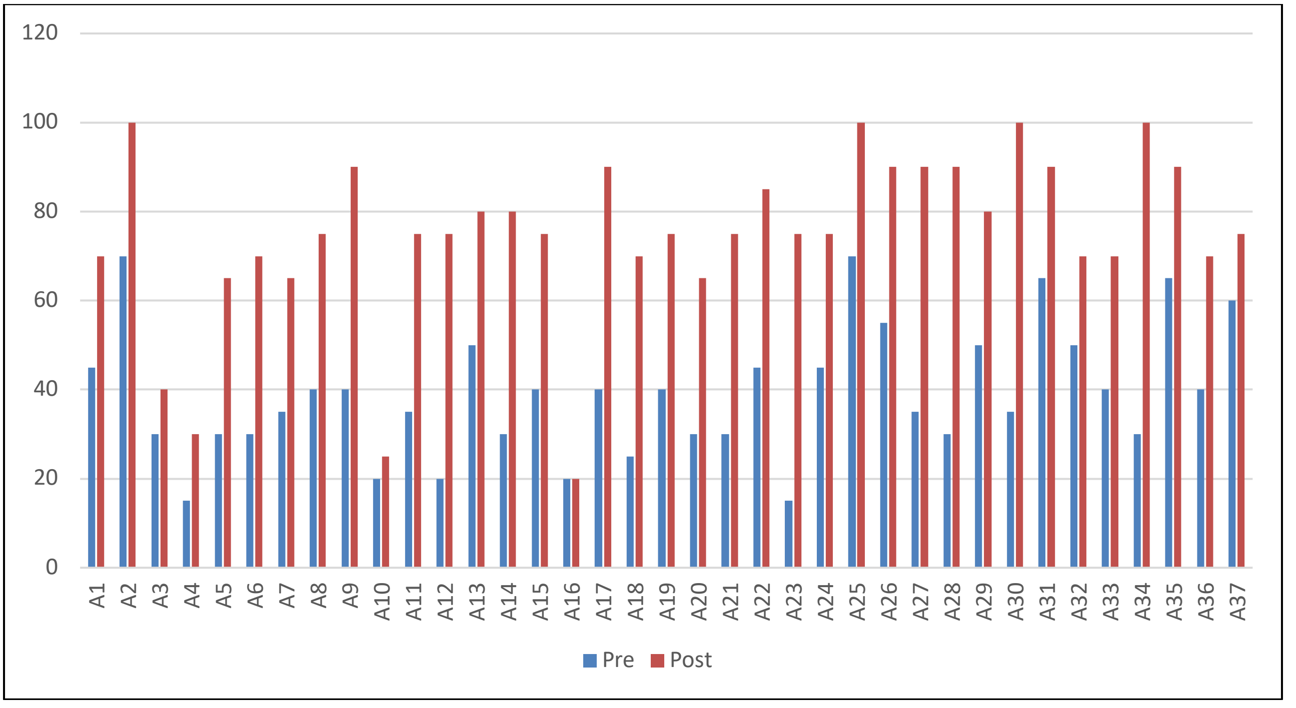

FIGURE 1 / Students' Conceptual Understanding Test Scores