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The Role of Reflection in Case-Based Learning to Develop Critical Thinking and Understanding of Genetic Application Concepts

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A R T I C L E I N F O

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A B S T R A C T

Case-Based Learning (CBL) has been applied in various disciplines to improve students' conceptual understanding and critical thinking. This study aims to analyze the role of reflection in CBL on the development of critical thinking and conceptual understanding in genetic applications. This study design uses a quantitative method with one-sample t-test analysis and Pearson correlation. The research sample consisted of students taking genetics courses at the college level. Data were collected through conceptual understanding tests and critical thinking tests. The results of the one-sample t-test showed that reflection significantly improved students' conceptual understanding ($p < 0.05$). In addition, Pearson's correlation analysis showed a significant positive relationship between conceptual understanding and critical thinking with a correlation coefficient of 0.588 ($p < 0.05$). These findings confirm that reflection in CBL can be an effective learning strategy in improving students' thinking skills. The implications of this study indicate that reflection needs to be systematically integrated into genetics learning to improve learning effectiveness. Further studies can explore the application of reflection in other fields of science as well as the use of technology to support digital-based reflection. Thus, the results of this study provide new insights into case-based learning innovation in higher education.

INTRODUCTION

Case-Based Learning (CBL) has become one of the effective methods in higher education, especially in science and technology. This approach allows students to develop critical thinking skills and conceptual understanding by linking theory to real-world applications (Thistlethwaite, J. E., et al., 2012). In the context of genetics, a deep conceptual understanding is needed to apply genetic principles in various fields, such as biotechnology, health, and agriculture (López-Belmonte et al., 2022). However, the challenges in learning genetics are the complexity of the concept and the low ability of students to think critically to analyze and solve problems (Sadler et al., 2023). Therefore, an effective learning strategy is needed to improve both aspects.

Reflection in case-based learning is one strategy that can help students connect theory with practice and improve conceptual understanding and critical thinking. Reflection allows students to evaluate their own thinking, identify gaps in understanding, and build new knowledge based on their learning experiences (Yeh, H.-C., et al, 2022). Recent studies have shown that reflection in active learning can increase students' cognitive engagement and strengthen the transfer of learning to real situations (Ismail, 2021).

Although reflection has been shown to be effective in enhancing learning, there are still limitations in research that specifically examines the role of reflection in case-based learning in genetics. Some of the main questions that arise in this study include:

1. Does reflection in case-based learning significantly improve conceptual understanding of genetic applications?
2. Does reflection in case-based learning contribute to improving students' critical thinking?
3. What is the relationship between conceptual understanding and critical thinking after the intervention of reflection in case-based learning?

Several previous studies have highlighted the benefits of reflection in improving critical thinking skills and conceptual understanding in various fields. Ismail (2021) emphasized that reflection supports metacognition and conceptual reinforcement, which ultimately improves students' ability to solve complex problems. In addition, a study by Benjamins, L. et al (2022) showed that reflection in experiential learning can help students understand the practical implications of the theories they learn. In the context of genetics, a study by Anderson, H. et al (2021) highlighted that a case-based learning approach involving reflection can improve students' understanding of genetic dynamics and its practical applications in medicine and biotechnology. Another study by Zhang, L., et al (2024) also confirmed that active involvement in case-based learning, supported by reflection, can accelerate the mastery of complex genetic concepts.

This study proposes a case-based learning approach that integrates reflection as a primary strategy to improve students' conceptual understanding and critical thinking in genetic applications. This approach involves a series of reflection activities, which aim to deepen students' understanding of genetic concepts and encourage more critical analysis of the cases studied. To measure the effectiveness of reflection, this study will use quantitative methods with one-

sample t-test analysis to evaluate the improvement of conceptual understanding and Pearson correlation analysis to identify the relationship between conceptual understanding and critical thinking.

This study provides innovative contributions to the field of genetics education by integrating reflection into case-based learning. Some of the new values of this study include:

1. Evidence-Based Approach: Using statistical analysis to evaluate the effectiveness of reflection in improving conceptual understanding and critical thinking.
2. Integration of Reflection Strategy: Developing a learning model that combines CBL with reflection as a systematic learning strategy.
3. Application in the Context of Genetics: Providing new insights into how reflection can be applied in genetics learning, which has not been widely explored in previous studies.

Thus, this study is expected to provide new insights for the development of more effective learning strategies in the field of genetics and contribute to improving the quality of science education in general.

METHODS

Research Design

This study uses a quantitative approach with a descriptive and inferential research design. The analysis used includes a one-sample t-test to evaluate differences in conceptual understanding against comparative values and Pearson correlation analysis to measure the relationship between conceptual understanding and critical thinking.

The design of this study aims to identify the effectiveness of reflection in case-based learning and the relationship between conceptual understanding and critical thinking in the context of genetic applications. This design is supported by previous research showing that reflection can improve understanding and critical thinking skills in students (Darmawati, D., et al., 2021).

Subjects of the Study

The subjects of the study were Biology Education students of Bantara University who took Genetics courses in semester 5. The sample was selected using a purposive sampling technique with the criteria of students who had obtained a basic theory of genetics but had not studied the application of genetics in case-based learning.

Research Procedure

a. Preparation Stage / Instrument Preparation
   1. Critical thinking test.
   2. Genetics application concept understanding test.
   3. Reflection activity guide.
   4. Case-based learning activity observation sheet.

b. Implementation Stage / Learning Design
   1. Implementation of case-based learning.
   2. Insertion of a reflection session at the end of each meeting to evaluate the thinking process and understanding of the concept.

Data Analysis

a. One Sample t-test

The one sample t-test is used to test whether the average understanding of the concept after the intervention is significantly higher than the comparison value (score 80). If the p value <0.05, it can be concluded that reflection in case-based learning has a significant effect on students' understanding of the concept.

b. Pearson Correlation Analysis

Pearson correlation analysis was conducted to determine the relationship between conceptual understanding and critical thinking. The correlation coefficient (r) is used to determine the direction and strength of the relationship between the two variables. If the p value <0.05, then the relationship is statistically significant.

Interpretation of Results

1. If the results of the one-sample t-test show $p < 0.05$, then reflection has a significant effect on conceptual understanding.

2. If the Pearson correlation coefficient shows a high r value with $p < 0.05$, then there is a significant positive relationship between conceptual understanding and critical thinking.

3. Conclusions are drawn based on empirical data and compared with previous studies in the literature (Waskita, P. I. et al., 2022).

This method is expected to provide empirical evidence regarding the effectiveness of reflection in case-based learning and the relationship between conceptual understanding and critical thinking in the context of genetic applications.

RESULTS AND DISCUSSION

Conceptual Understanding of Conservation Genetics

In general, the reflections analyzed showed a very good to excellent understanding (average 92) of conservation genetics, its real-world applications, and its impacts on human life and ecosystems. Conceptual understanding included in-depth analysis, mature critical thinking, and strong relevance to real conservation challenges.

Some of the main aspects obtained from these reflections include:

1. Linkages between Genetics and Species Conservation – Awareness that genetic mechanisms play a critical role in conservation efforts, including in species restoration, monitoring genetic diversity, and mitigating extinction risks.

2. Real-Life Impacts – Reflections showed an understanding of how conservation genetics not only protects species but also impacts the balance of ecosystems and human life.

3. Application of Scientific Concepts – The use of strong scientific concepts, such as genetic mutation, genetic diversity, and restoration strategies, has been clearly linked to real conservation problems.

4. Opportunities for Improvement – Some reflections could be strengthened with further elaboration on specific genetic mechanisms, more diverse conservation methods, broader ecological impacts, and links to economic aspects of conservation.

Overall, the understanding of the concept of conservation genetics in this reflection has been very good and can be further improved with deeper exploration of the technical aspects and the integration of richer conservation strategies.

The results of the statistical test showed a p-value that was much smaller than 0.05, indicating that there was a significant difference between the average sample score of 92.08 and the comparison value of 80. Therefore, the null hypothesis (H_0) is rejected, and it can be concluded that the reflection intervention has a significant effect on improving students' conceptual understanding.

Reflection in the context of learning acts as a metacognitive tool that helps students realize their thinking processes, organize new information, and connect it to previously acquired knowledge (Widiyanti & Nugroho, 2021). When reflection is carried out systematically, students are able to evaluate and reconstruct their understanding more deeply, which in turn improves their mastery of important concepts in learning.

A study by Permatasari and Handayani (2022) showed that the application of reflective strategies in science learning significantly improved students' ability to understand abstract concepts, because students were encouraged to elaborate on the material and relate it to their own learning experiences. Reflection also strengthens conceptual understanding because it allows for a more meaningful internalization process of knowledge (Yusuf et al., 2021).

In addition, reflection helps students identify misconceptions that may occur during the learning process. By recognizing and correcting these misconceptions through reflection, conceptual understanding becomes more accurate and deeper (Sari & Putra, 2023). This is in line with the constructivist approach in education, where students actively construct their own knowledge through interaction with materials and learning experiences.

Thus, these findings confirm that reflective strategies are not just tools, but are an important component in designing meaningful learning that is oriented towards strengthening conceptual understanding.

Relationship between Conceptual Understanding and Critical Thinking

Results of the independent two-sample t-test: t statistic: 1.48; p value: 0.1523. Since the p value is greater than 0.05, there is no significant difference between the Conceptual Understanding and Critical Thinking scores. This indicates that both groups have relatively similar value distributions in this context.

The results of the Pearson correlation analysis showed a significant positive relationship between conceptual understanding and critical thinking skills after being given a reflection intervention in case-based learning. The correlation coefficient value of 0.588 and the significance value of 0.044 ($p < 0.05$) indicate that an increase in conceptual understanding tends to be followed by an increase in critical thinking skills.

This finding supports the view that a deep understanding of concepts is an important prerequisite for the formation of critical thinking skills (Hidayat et

al., 2022). In the context of science education, students who understand concepts well tend to be able to evaluate information, identify problems, and formulate solutions logically and systematically.

Reflection as an intervention in case-based learning functions as a catalyst in the process of internalizing concepts. Reflection allows students to review their understanding, become aware of knowledge gaps, and develop deeper reasoning (Fitriani et al., 2023). In case-based learning, the reflective process is very important because it encourages students to relate knowledge to real experiences, which ultimately improves higher-order thinking capabilities.

Research by Kusumastuti et al. (2021) also shows that problem-based learning approaches and reflection can significantly improve the quality of students' critical thinking. Reflection encourages the elaboration of concepts that have been learned, so that understanding is not superficial but more conceptual and applicable. Thus, the positive correlation between conceptual understanding and critical thinking skills found in this study can be explained through the strategic role of reflection activities in deepening students' learning experiences.

Furthermore, the integration of a reflective approach in case-based learning can be an effective strategy in shaping 21st-century competencies, including critical thinking, communication, and complex problem solving (Setiawan & Sukardi, 2021). Therefore, teachers and lecturers are advised to continue to develop learning models that not only emphasize the transfer of information but also provide space for students to reflect on their learning process.

Critical Thinking Skills

In general, the data shows that the level of critical thinking in the analyzed statements is in the high to very high category (average 87.8). Several main aspects that reflect critical thinking skills include:

1. In-depth Analysis – Most statements demonstrate a strong understanding of the issues discussed, with in-depth exploration of the various factors that influence the problem.
2. Evidence-Based Argumentation – Statements that have empirical support and real examples tend to score higher, indicating the importance of data in strengthening claims.
3. Solution Evaluation – The ability to weigh the advantages and disadvantages of the proposed solution is a differentiating factor in assessing the quality of critical thinking, where statements that are more structured in evaluating solutions tend to excel.
4. Alternative Exploration – Statements with a broader scope that compares various approaches or perspectives indicate a more mature level of critical thinking.
5. Balance of Perspectives – The ability to consider various points of view with high objectivity is an indicator of stronger critical thinking.
6. Opportunities for Improvement – Some statements can be improved by adding more empirical references, deepening the exploration of implementation challenges, and strengthening arguments with quantitative data.

Overall, although it has shown a high level of critical thinking, improvements in presentation format, data support, and exploration of weaknesses from various perspectives are still needed to achieve a more optimal level.

The results of the one-sample t-test showed a statistical value of t of 4.418 and a p-value of 0.00103, which means it is smaller than the significance level of 0.05. Thus, the null hypothesis (H_0) is rejected and it can be concluded that there is a significant difference between the average critical thinking ability of participants after the reflection intervention with a comparison value of 80. This finding confirms that reflection has a significant influence on improving critical thinking skills.

Reflection in learning is not just an additional activity, but an integral part of the metacognitive process that encourages students to review learning experiences, realize mistakes, and build deeper understanding (Indrawati & Pratama, 2021). The reflective process provides space for students to develop high-level thinking skills, such as analyzing, evaluating, and synthesizing information—the main components of critical thinking.

Similar research by Zahro et al. (2022) showed that students who were actively involved in reflective activities showed significant improvements in critical thinking skills compared to the group that only received regular instructions. Reflection-based interventions help students to connect theory with practice, while evaluating and assessing the arguments and decision-making processes they carry out during learning.

In addition, in the context of problem-based and case-based learning, reflection becomes an important mechanism for consolidating concepts and problem-solving strategies, which ultimately strengthens conceptual mastery and critical thinking (Wulandari & Hamidah, 2023). When reflection is carried out in a structured manner and guided by educators, the results can be much more effective in developing students' intellectual potential.

Therefore, the results of the statistically significant test in this study confirm the importance of including reflection as a systematic part of a learning strategy aimed at improving critical thinking skills.

CONCLUSIONS AND RECOMMENDATIONS

This study aims to answer three main questions related to the effectiveness of reflection in case-based learning on the topic of genetic applications. First, the results of statistical tests show that reflection in case-based learning significantly improves students' conceptual understanding. The average score that far exceeds the comparison value indicates that students gain a deeper conceptual understanding after being given reflective intervention. Second, reflection is also proven to contribute significantly to improving critical thinking skills. This is shown by the statistically significant test results, which indicate that reflection encourages students to examine, evaluate, and synthesize information more deeply in the context of solving cases. Third, the existence of a significant positive relationship between conceptual understanding and critical thinking skills indicates that improvements in one aspect tend to be followed by improvements

in other aspects. This correlation strengthens the understanding that the two are closely related in the framework of reflection-based learning.

FURTHER STUDY

These findings open up opportunities for the development and application of broader research. Reflection can be explored in various other biology courses or topics, such as biotechnology, evolution, and ecology, to see the consistency of its effects in different contexts. Further research can also develop a systematic reflection-based learning model or tool that is integrated with a digital approach, such as e-portfolio or video-based reflection.

In addition, a quantitative approach can be combined with a qualitative approach to dig deeper into students' experiences in undergoing the reflective process, as well as how it shapes their critical thinking patterns and conceptual understanding. The development of more specific and contextual evaluation instruments is also a strategic step to measure the effectiveness of reflection more comprehensively.

In practice, the results of this study can be used as a basis for designing a curriculum that integrates reflection as part of the active learning process, in order to produce graduates who are not only cognitively capable, but also critical and adaptive to complex problems in the fields of genetics and biology in general.

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