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PBLRQA Strategy on Metacognitive Skills and Higher-order Thinking of Students in the Genetics Course

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ABSTRAK

Rendahnya kemampuan metakognitif dan berpikir tingkat tinggi menyebabkan mahasiswa kesulitan dalam memahami materi mata kuliah genetika. Penelitian ini bertujuan untuk menganalisis efektivitas strategi PBLRQA, PBL, dan RQA terhadap keterampilan metakognitif dan berpikir tingkat tinggi siswa. Penelitian ini menggunakan desain non-equivalent control group pretest-posttest design. Pengambilan sampel dilakukan terhadap 118 mahasiswa yang terdiri dari empat kelas dengan menggunakan teknik sampling jenuh. Instrumen penelitian yang digunakan berupa lembar observasi aktivitas dosen dan mahasiswa, tes keterampilan metakognitif berbasis essay, dan tes pilihan ganda keterampilan berpikir tingkat tinggi. Data aktivitas dosen dan mahasiswa dianalisis berdasarkan persentase indikator yang berkategori tinggi dan sangat tinggi secara sintaksis. Data keterampilan metakognitif dan berpikir tingkat tinggi dianalisis menggunakan tes Normalized Gain dan Independent Kruskal Wallis. Temuan penelitian menunjukkan bahwa penerapan strategi PBLRQA, PBL, dan RQA tidak efektif dalam meningkatkan keterampilan metakognitif dan keterampilan berpikir tingkat tinggi siswa. Untuk menindaklanjuti temuan tersebut, diperlukan penelitian lebih lanjut untuk mengeksplorasi keterlibatan gaya belajar dan dukungan sosial terhadap keterampilan metakognitif dan keterampilan berpikir tingkat tinggi siswa, dengan fokus pada penerapan strategi PBLRQA dan RQA.

ABSTRACT

Low metacognitive abilities and high-level thinking cause students to have difficulty understanding genetics course material. This research aims to analyze the effectiveness of PBLRQA, PBL, and RQA strategies on students' metacognitive and higher-order thinking skills. This research uses a non-equivalent control group pretest-posttest design. Sampling was carried out on 118 students consisting of four classes using saturated sampling techniques. The research instruments used were observation sheets on lecturer and student activities, essay-based metacognitive skills tests, and multiple-choice tests on high-level thinking skills. Lecturer and student activity data were analyzed based on the percentage of indicators categorized as high and very high syntactically. Data on metacognitive skills and higher-order thinking were analyzed using the Normalized Gain and Independent Kruskal Wallis tests. Research findings show that implementing PBLRQA, PBL, and RQA strategies is ineffective in improving students' metacognitive and higher-order thinking skills. To follow up on these findings, further research is needed to explore the involvement of learning styles and social support on students' metacognitive skills and higher-order thinking skills, focusing on implementing PBLRQA and RQA strategies.

1. INTRODUCTION

Tertiary education is not solely focused on mastering scientific concepts, but also on the development of thinking skills (Alsaleh, 2020). This condition enables students to adapt to the rapid and increasingly complex changes in the 21st century (Lyons et al., 2019; M. M. Rahman, 2019). Some of the skills in question include metacognitive skills and higher-order thinking (Albab et al., 2020; Nurman et al., 2018). Metacognitive skills have a pivotal role in monitoring and regulating cognitive processes (Ansari et al., 2019; Jacobs & Paris, 1987; Kustiana et al., 2020), and assist students in understanding when, why,

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where, and how to apply their knowledge to solve problems (Carr & Jessup, 1995). Furthermore, higher-order thinking skills, encompassing cognitive process dimensions such as analyzing, evaluating, and creating, contribute to effectively solving social, scientific, and practical problems (Shakirova, 2007). Simultaneously, these skills collectively serve as the foundation for effective and sustainable learning (Jager, 2019; Hamzah et al., 2022; Kazemian et al., 2021; Rahayu et al., 2020). Students will have the ability to identify weaknesses in their understanding and take steps to improve them, thus creating a more dynamic and efficient learning environment. This will serve as a strong basis for enhancing students' understanding of their selected field of study, as is the case with biology students.

In studying biology, the best approach is to understand genetics as its fundamental structure (Hariyadi, 2015). The genetics course plays a crucial role in shaping an understanding of how genetic information is inherited and influences organism characteristics (Cavallo, 1996; Kiliç & Sağlam, 2014; M. C. P. J. Knippels et al., 2005; Murray-Nseula, 2011). Understanding genetics is highly relevant to various fields, including medicine, agriculture, technology, and various other branches of biology (Bell & Gilan, 2020; Henry, 2020; Katoch et al., 2021; Pereira et al., 2020). Therefore, students with a strong foundational grasp will have an advantage in their careers and the potential for future advancements in science and technology. Nevertheless, studying genetics can be challenging for students due to its complex and abstract nature (Knippels, 2002). Genetics also involves understanding mathematics and statistics (Ewens, 2013; Lv et al., 2012). This can be a barrier for some students lacking basic arithmetic skills and sufficient background in biology (Desender & Sasanguie, 2022; Skagerlund et al., 2019; Speth et al., 2014). Hence, metacognitive and higher-order thinking skills are crucial in helping students overcome these challenges.

Based on previous relevant research, it was found that the metacognitive skills of undergraduate students are still relatively low (Herlanti et al., 2019). This is supported by similar findings related to students' higher order thinking skills (Fitriani et al., 2019). Furthermore, based on the distribution of questionnaires in August 2021 using the instrument, it was found that 74.51% of Biology Education students at Tadulako University experienced difficulties in attending genetics lectures (Suryanti et al., 2019). The factors causing this include difficulty understanding learning materials (62.75%), difficulty finding adequate learning resources (37.25%), difficulty accessing appropriate learning resources (31.37%), and limited time during lectures (27.45%). This condition may arise due to students' lack of ability to select appropriate learning methods or techniques for the type of material, organizing their study schedules regularly and systematically, a lack of awareness about when they understand the material well and when they encounter difficulties, as well as their inability to evaluate the extent of their understanding or mastery of the material (Ali & Razali, 2019; Bringman-Rodenbarger & Hortsch, 2020; Concina, 2019). Students may also be less accustomed to using high-order thinking skills to integrate information from learning resources and evaluate it to form a better understanding (Anderson et al., 2001; Rustaman, 2011; Rahayu et al., 2021). The inability of students to comprehend and master course materials has a detrimental impact on their participation in classroom lectures (Darmawati et al., 2011). Although conventional teaching methods are still frequently used, efforts to implement student-centred learning approaches continue. However, scepticism about its effectiveness has arisen due to the inadequate level of student participation. The decision to use conventional strategies is also influenced by the ease of classroom management and structured content delivery. Nevertheless, feedback is consistently provided to help students enhance their understanding.

In order to address the aforementioned issues, the implementation of learning strategies that can stimulate the development of metacognitive skills and higher-order thinking in students is required. One of the proposed strategies is PBLRQA, which combines the syntax of the PBL (Problem-Based Learning) and RQA (Reading Questioning Answering) strategies (Nurman et al., 2018). The implementation of the PBL strategy can train students to solve problems cooperatively (Allen et al., 2011). The implementation of the RQA strategy will involve students in activities such as reading, questioning, and answering (Iqbal & Hariyadi, 2015). Therefore, the combination of these two strategies will encourage students to be more active in seeking information and problem-solving, thus enhancing their thinking skills (Bahri & Idris, 2017). The PBLRQA strategy is effective in improving students' metacognitive skills in the animal physiology course at Makassar State University (Bahri et al., 2019). This is also supported by similar findings regarding students' creative thinking skills in genetics courses at the State University of Malang (Angraini et al., 2022) .

Hence, this study is important to ensure the effectiveness of the PBLRQA strategy in different contexts. Although the PBLRQA strategy has proven to be effective in one group of students, it cannot be directly assumed that its effectiveness will be the same in a different group of students. In addition, while there are similarities between this study and previous studies investigating students' metacognitive skills and higher order thinking in genetics learning, there is also a key difference which lies in the quantitative approach used in this study (Sumampouw, 2011). Moreover, the analysis of students' responses to both numeric and non-numeric questions to measure metacognitive skills is a new approach that has not been done in previous research. Therefore, this study aims to analyze the effectiveness of the PBLRQA, PBL, and RQA strategies on students' metacognitive skills and higher-order thinking in the genetics course.

2. METHOD

This study employed a non-equivalent control group pretest-posttest research design. This design was utilized to compare the experimental groups (classes A, B, and D) implementing three different learning strategies (PBLRQA, PBL, and RQA) and the control group (class C) using conventional teaching methods. Data were collected through pre-test (before treatment) and post-test (after treatment) to assess the changes occurring in each group. The research population consisted of 118 students from the Biology Education Program at Tadulako University participating in the Genetics course during the academic year 2021/2022. In this study, a saturated sampling technique was used to select the research sample, making all classes within the population a part of the research sample. Data collection was carried out through observation and tests. Observation sheets containing indicators of the syntax of each learning strategy were used to observe the activities of both the lecturer and students during the lecture process. The instrument, which had undergone validity testing, consisted of a scoring scale: not implemented (0), partially implemented (1), and fully implemented (2). On the other hand, metacognitive skills were assessed using 10 essay questions (7 non-numeric and 3 numeric questions), while higher-order thinking skills were measured using 11 multiple-choice questions. The test instruments were validated through construct validity and Pearson's Product-Moment Correlation (content validity). The reliability of the test instruments was calculated using Cronbach's alpha test and indicated high reliability (essay questions = 0.88 and multiple-choice = 0.87). Additionally, in evaluating students' answer sheets for non-numeric questions, a 0 to 7 scale rubric was used (Corebima, 2006). While for numeric questions, a rubric was used, consisting of a scoring scale: not fulfilled (0), partially fulfilled (1), and fulfilled (2). Construct validity testing confirmed that the assessment rubric for numeric questions was also valid (Corebima, 2006; Veenman & Cleef, 2019).

Data obtained from observation sheets were calculated by dividing the obtained score by the maximum score and then multiplying by 100. Syntax analysis was conducted based on criteria, namely: very high, high, moderate, low, and very low (Najmi et al., 2021). The percentage of very high and high categories was used to determine the activities of the lecturer and students based on the criteria: very inadequate, inadequate, sufficient, good, and very good (Eliaumra, 2019; Riduwan, 2009). On the other hand, pre-test and post-test data from each class were analyzed using the Normalized Gain test (Hake, 1998) and hypothesis testing (Independent Kruskal Wallis). Hypothesis testing was employed because the obtained data were not normally distributed based on the results of the Shapiro-Wilk test using IBM SPSS 25.0 64-bit software (α = 0.05).

3. RESULT AND DISCUSSION

Result

The results of observing the activities of the lecturer and students in each learning strategy can be seen in Figure 1.

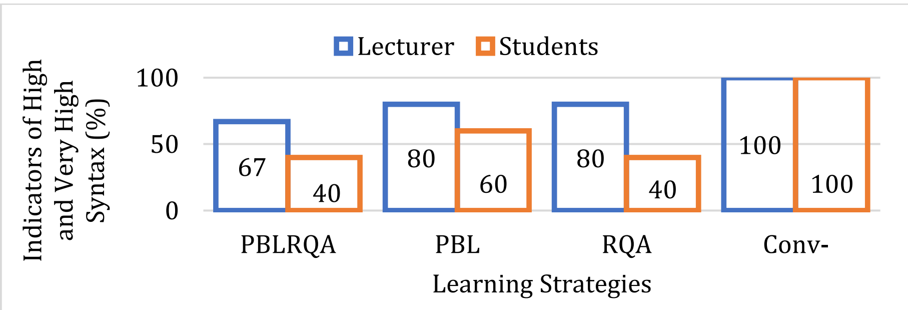

Figure 1. Activities of Lecturer and Students

Based on Figure 1, it can be explained that the activities of the lecturer in implementing the PBLRQA, PBL, RQA, and conventional strategies are categorized as good, good, good, and very good. Furthermore, it can be observed that the level of student participation in implementing these four learning strategies also varies. The level of participation in each learning strategy is categorized as low, moderate, low, and very good.

The Effectiveness of PBLRQA, PBL, and RQA Strategies on Students' Metacognitive Skills. The results of the pre-test and post-test on the descriptive (non-numerical) questions can be seen in Figure 2, and Figure 3

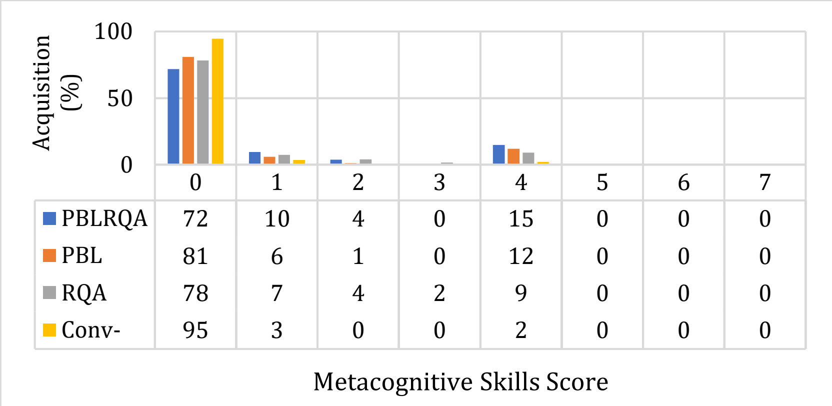

Figure 2. Percentage of Students' Metacognitive Skill Assessment in the Pre-Test of Non-Numerical Questions

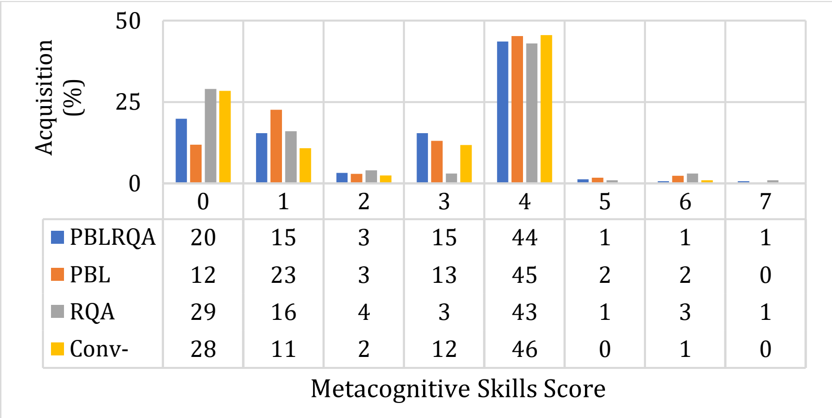

Figure 3. Percentage of Students' Metacognitive Skill Assessment in the Post-Test of Non-Numerical Questions

Based on Figure 2, it can be explained that in each class studied, the highest percentage of scores obtained was 0. After the post-test was conducted (Figure 3), the highest percentage was achieved with a score of 4. Meanwhile, based on the pre-test results for numerical questions, no students provided answers. When the post-test was conducted, the results can be seen in Figure 4.

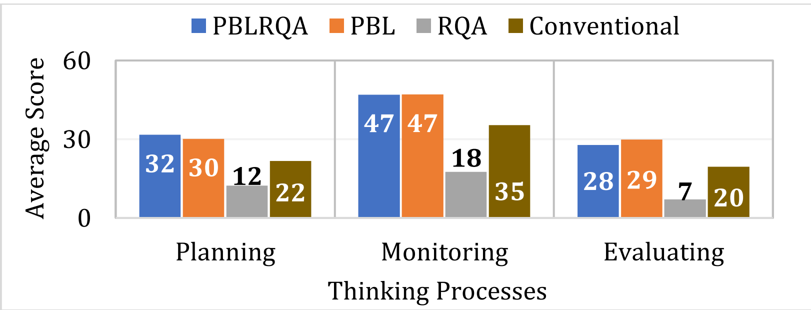

Figure 4. Average Scores of Students' Metacognitive Skills in the Post-Test for Numerical Questions

Based on Figure 4, shows that the monitoring skill in each class studied has the highest score, while the evaluating skill has the lowest score. Furthermore, the effectiveness of each learning strategy can be seen in Figure 5.

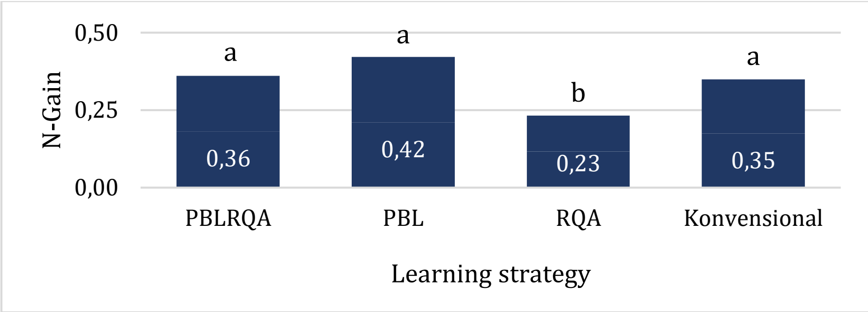

Figure 5. Effectiveness of Learning Strategies on Students' Metacognitive Skills

Based on Figure 5, it can be explained that there is no significant difference in effectiveness between the PBLRQA and PBL strategies. The same results were also found between the PBLRQA strategy and the conventional strategy, as well as between the PBL strategy and the conventional strategy. However, a significant difference was found between the RQA strategy and the other three learning strategies.

The Effectiveness of PBLRQA, PBL, and RQA Strategies on Students' Higher-Order Thinking Skills. The average scores for each cognitive process of higher-order thinking skills measured through the pre-test and post-test can be seen in Table 1.

Table 1. Average Scores of Students' Higher-Order Thinking Skills

Dimension of Cognitive Processes	Learning Strategies	Pre-Test	Post-Test
C4	PBLRQA	8.5	48.5
	PBL	12.9	43.6
	RQA	22	29
	Conventional	17.1	46.5
C5	PBLRQA	1	17.3
	PBL	9	22
	RQA	7.5	14.2
	Conventional	4	16.2
C6	PBLRQA	0	5.8
	PBL	0	5.4
	RQA	3	1.7
	Conventional	2.9	2.9

Based on Table 1, shows an improvement in each dimension of cognitive processes in each of the examined classes, except for cognitive process C6 in the class that implemented the RQA and conventional strategies. Furthermore, the effectiveness of each learning strategy can be seen in Figure 6. Based on Figure 6, it can be explained that the non-significant differences between the learning strategies yield similar results as seen in Figure 5.

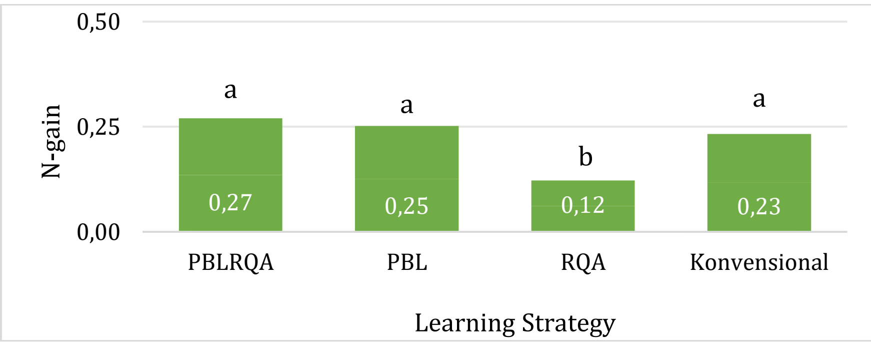

Figure 6. Effectiveness of Learning Strategies on Students' Higher-Order Thinking Skills

Discussion

Based on the findings of this research (Figure 3), the percentage of students scoring 4 was found to be the highest in each class. Most students demonstrated the ability to comprehend and solve problems, as well as to organize information effectively. Clear language proficiency was reflected in the correct use of grammar. However, the lack of development in cognitive strategies and writing skills led to a tendency for students to use the same sentence patterns. Effective organization of the thinking process can enhance students' cognitive abilities, including their awareness of how to access and store information in long-term memory (Cowan, 2020; Forsberg et al., 2021; Jones et al., 2020; Morrison & Richmond, 2020; Siegel & Castel, 2019; Komori, 2016). Although it appears that students have begun to recognize the importance of this and are trying to apply elaboration strategies rather than just rehearsal strategies, they still struggle to improve their skills in expressing ideas in writing. Mastering writing skills requires balanced attention and practice in language, content, organization, communication purpose, vocabulary, punctuation, and spelling (Liunokas, 2020). It is important for individuals to strike the right balance between focus and self-awareness of the cognitive strategies employed to complete cognitive tasks (Norman, 2020).

Students tend to be capable of monitoring their thinking activities effectively but are less meticulous in planning and evaluating the completion of cognitive tasks (Figure 4). However, planning is a key component of metacognitive skills (Zepeda et al., 2019). Proper planning can support the monitoring and evaluation processes, enabling students to identify errors and find better solutions to problem-solving, thus helping them revise their prior knowledge. Surprising results are seen in Figure 5, the application of PBLRQA, PBL, and RQA strategies is not effective in improving students' metacognitive skills. This finding contradicts previous research which explains that the PBLRQA strategy improves students' metacognitive skills in animal physiology courses . (Bahri et al., 2019). Similarly, another study reported the positive impact of PBL strategy on students' metacognitive skills and reasoning in solubility and solubility product (Haryani et al., 2018). Furthermore, there are studies that show that the RQA strategy increases students' metacognitive awareness, especially in plant taxonomy courses (Rahman et al., 2020).

Based on these findings, there is a possibility that the causes are influenced by weaknesses in the applied learning strategies. The PBL strategy is less effective if students' understanding is still inadequate (Saleh, 2013). The implementation of PBL is also challenging for lecturers in managing diverse classes, requiring long class hours and a high level of student motivation (Albanese & Dast, 2014). On the other hand, the RQA strategy is susceptible to misconceptions because students may have different views on the material they read, potentially resulting in less accurate questions and answers (Darmayanti, 2015). The noteworthy result is that even though the PBLRQA strategy was designed to address the weaknesses present in both the PBL and RQA strategies. The findings are, in fact, similar to both of these strategies (Nurman et al., 2018). In terms of methodology, this study uses different research instruments from previous studies. There are studies that use tests and questionnaires in the form of narrative Metacognitive Activities Inventory (MCA-I) (Haryani et al., 2018). And also, some use the Metacognitive Awareness Inventory (MAI) which has been validated and analyzed using confirmatory factor analysis (CFA) (Rahman et al., 2020). However, although this study adopted the same rubric as the previous studies, the results found were still contradictory (Bahri et al., 2019). Assessing metacognition is a complex task (Schraw, 2000). Although various instruments can be used, assessing it becomes difficult because metacognition involves various complex mental processes (Ozturk, 2017). Furthermore, using rubrics to assess students' test results tends to provide assessments on measurable and observable aspects, making qualitative aspects such as deep understanding or insight difficult to measure precisely (Sadler, 2009, 2014; Torrance, 2007). Questionnaires have their shortcomings, namely individual reference points that can result in low predictive values because students may compare themselves to the best or worst students in the class (Ozturk, 2017). This explanation underscores that a single instrument cannot be relied upon to measure students' metacognitive skills.

Furthermore, several psychological factors of students need to be considered, such as cognitive styles (Samosir et al., 2019; Shamsuddin & Kaur, 2020; Gajić et al., 2021; Syaputra et al., 2022), cognitive or social challenges (Hadwin et al., 2018; Říčan & Chytrý, 2020), motivation (Gabriel et al., 2020), and anxiety (Rui, 2022) that can influence students' levels of participation in lectures, as seen in the varied results in Figure 1. This condition indicates that each student has different levels of metacognitive skills, with some students possibly requiring more guidance and practice than others (Veenman et al., 2006). In the context of the explanations above, this study provides valuable insights into students' metacognitive skills. Although the research results indicate challenges in developing cognitive strategies and writing skills, most students already have a good understanding of the course material. Contradictory results compared to previous research indicate the complexity of the factors influencing metacognitive skills, including the selection of measurement tools or research instruments. Furthermore, this study also encourages a deeper understanding of how cognitive styles, cognitive challenges, motivation, and anxiety can affect students' metacognitive skills. Therefore, these findings make a significant contribution to the development of better learning strategies in the future.

Based on Table 1, the impact resulting from the implementation of the PBLRQA, PBL, and conventional strategies tends to be more significant in enhancing the dimensions of cognitive processes analyzing (C4) and evaluating (C5), while the RQA strategy has limited impact on both aspects. However, the implementation of each learning strategy has a lower impact on the dimension of cognitive processes related to creating (C6). These findings indicate that students have a low foundational skill in critically analyzing and understanding information. There is a tendency to rely on existing knowledge and follow instructions without adequate critical thinking. The findings (Figure 6) illustrate that the implementation of the PBLRQA, PBL, and RQA strategies is not effective in improving students' higher-order thinking skills. This finding is intriguing because it is different from previous research which explains that PBLRQA can significantly improve the critical thinking skills of elementary school teacher education students at Pattimura University (Leasa et al., 2023). Similarly, there is research that reveals that the application of PBL can improve students' critical thinking skills and problem solving skills in chemistry subjects at BTB Balige High School (Simatupang et al., 2021). Lastly, there is also research that reports that the RQA strategy can be used as an alternative to improve the higher order thinking skills of undergraduate students (Nasrudin & Azizah, 2019).

However, concerning these findings, it should be noted that there are weaknesses in the applied learning strategies. The PBL strategy may be less effective if students' understanding is inadequate (Saleh, 2013). Additionally, the implementation of PBL is suitable for only some topics, presents challenges for lecturers in managing diverse classrooms, requires a significant amount of class time, demands high motivation from students to solve problems, and sometimes the required learning resources are not fully available. When students identify learning problems, these problems are often expressed in overly general terms, resulting in inefficient learning and unfocused discussions (Albanese & Dast, 2014). The RQA strategy is susceptible to misconceptions because each student can have different views on the material they read, requiring lecturers to actively guide students in clarifying their understanding of the course material (Darmayanti, 2015). Moreover, misconceptions can arise because each student uses their ideas to interpret reading materials, sometimes resulting in questions and answers that are less accurate (Dahar, 2011). Interestingly, the combination of these two strategies (PBLRQA) also yields similar results. Therefore, it must be acknowledged that this strategy may not always be suitable for every context and subject matter. Moreover, the combination of these two strategies also has implications for increased resource requirements.

Not only that, but factors within students also play a role in the effectiveness of learning strategies. Some of these factors include learning styles (Bajaj & Sharma, 2018; Samosir et al., 2019; Shamsuddin & Kaur, 2020; Gajić et al., 2021; Syaputra et al., 2022), cognitive load (Kirschner & Sweller, 2018; Redifer et al., 2021), social loafing (Karau & Wilhau, 2020), and students' mindset (Xu et al., 2021). As seen from the variation in results in Figure 1, these factors are believed to affect students' levels of participation in class. This condition contributes to the enhancement of students' critical, creative, collaborative, and constructive thinking skills (Supena et al., 2021). Therefore, even though these findings are not in line with previous research, they emphasize the need for further research in the implementation of effective learning strategies to enhance students' higher-order thinking skills, especially in the field of genetics. Additionally, to assess higher-order thinking skills, the identification of student activities also needs to be conducted. Hence, the simultaneous relationship between the factors influencing the results of this study needs further investigation (Rozi et al., 2021).

4. CONCLUSION

In this study, no differences in effectiveness were found among the PBLRQA, PBL, and RQA strategies. The implementation of these three teaching strategies was ineffective in improving students' metacognitive skills and higher-order thinking in the genetics course. These findings depict the complexity of various factors influencing the research outcomes. Therefore, further research is required to explore the factors simultaneously affecting students' metacognitive skills and higher-order thinking.

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