

## Critical Thinking in Biology Education Students through Reading, Questioning, and Answering (RQA) and Gamification Working Together

Angsoka Dwipayana Marthaliakirana<sup>1</sup>, Herianto<sup>2</sup>, Aziza Karenina<sup>3</sup>, Nuris Fattahillah<sup>3</sup>, Andika Febrian<sup>3</sup>, Hayatining Suci Abdilah<sup>4</sup>

<sup>1</sup> Biology Education, Sultan Ageng Tirtayasa University, Serang, Indonesia

<sup>2,4</sup> Physics Education, Sultan Ageng Tirtayasa University, Serang, Indonesia

<sup>3</sup> Science Education, Sultan Ageng Tirtayasa University, Serang, Indonesia

Email: [Angsoka.dwipayana@untirta.ac.id](mailto:Angsoka.dwipayana@untirta.ac.id), [herianto@untirta.ac.id](mailto:herianto@untirta.ac.id), [aziza.karenina@untirta.ac.id](mailto:aziza.karenina@untirta.ac.id), [nuris.fattahillah@untirta.ac.id](mailto:nuris.fattahillah@untirta.ac.id), [andika.febrian@untirta.ac.id](mailto:andika.febrian@untirta.ac.id), [hayatining.suci@untirta.ac.id](mailto:hayatining.suci@untirta.ac.id)

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### Abstract

#### Abstract (English)

Critical thinking is an essential competency in learning that supports knowledge development through the evaluation of concepts, content, and problems. However, the level of students' critical thinking skills remains relatively low. This study aimed to assess the impact of RQA-assisted gamification on improving students' critical thinking abilities. A quasi-experimental method with a one-group pretest-posttest design was employed. This design was used to examine the effect of the RQA-assisted gamification model on students' critical thinking skills by comparing their performance before and after the treatment. The sample consisted of 30 biology education students from Sultan Ageng Tirtayasa University, Indonesia. Data were collected using essay tests designed based on critical thinking indicators such as interpreting, analyzing, evaluating, concluding, and explaining. The instrument consisted of 10 valid and reliable items. Data were analyzed using the Wilcoxon signed-rank test at a 0.05 significance level. The findings demonstrated that RQA-assisted gamification positively influenced students' critical thinking, with an average improvement of 47.27%. These findings suggest that RQA-assisted gamification can be implemented to enhance critical thinking in biology learning.

**Keywords:** Biology Education Student; Critical Thinking Skills; Gamification; RQA

#### Abstrak (Indonesia)

Berpikir kritis merupakan kompetensi penting dalam pembelajaran yang mendukung pengembangan pengetahuan melalui evaluasi konsep, isi, dan masalah. Namun, tingkat kemampuan berpikir kritis siswa masih relatif rendah. Penelitian ini bertujuan untuk menilai dampak gamifikasi berbasis Membaca, Bertanya, dan Menjawab (gamifikasi berbasis RQA) terhadap peningkatan kemampuan berpikir kritis siswa. Metode kuasi-eksperimental dengan desain pretest-posttest satu kelompok digunakan. Desain ini digunakan untuk menguji pengaruh model gamifikasi berbasis RQA terhadap

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kemampuan berpikir kritis siswa dengan membandingkan kinerja mereka sebelum dan sesudah perlakuan. Sampel terdiri dari 30 mahasiswa biologi dari Universitas Sultan Ageng Tirtayasa, Indonesia. Data dikumpulkan melalui tes esai, yang dirancang berdasarkan kriteria berpikir kritis seperti menafsirkan, menganalisis, mengevaluasi, menyimpulkan, dan menjelaskan. Instrumen terdiri dari 10 item yang valid dan reliabel. Data dianalisis menggunakan uji peringkat bertanda Wilcoxon pada tingkat signifikansi 0,05. Hasil penelitian menunjukkan bahwa gamifikasi yang dibantu RQA berpengaruh positif terhadap kemampuan berpikir kritis siswa, dengan peningkatan rata-rata sebesar 47,27%. Temuan ini menunjukkan bahwa gamifikasi yang dibantu RQA dapat diimplementasikan untuk meningkatkan kemampuan berpikir kritis dalam pembelajaran biologi.

Kata kunci: Siswa Pendidikan Biologi; Kemampuan Berpikir Kritis; Gamifikasi; RQA.



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#### **Corresponding Author:**

Angsoka Dwipayana Marthaliakirana

Biology Education, Sultan Ageng Tirtayasa University, Serang, Indonesia

Affiliation ; [Angsoka.dwipayana@untirta.ac.id](mailto:Angsoka.dwipayana@untirta.ac.id) / ORCID : [0000-0003-3887-9308](https://orcid.org/0000-0003-3887-9308)

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## **1. INTRODUCTION**

Critical thinking is one of the higher-order thinking skills that students must possess as 21st-century learners. Critical thinking is the ability to reflect on oneself through independent thinking (Saleh et al., 2023). Critical thinking is essential in facing the complexity of global problems. Critical thinking skills are essential for students to gain conceptual understanding (Marthaliakirana et al., 2022). Critical thinking is a crucial thinking skill in the learning process, especially in biology (Danil et al., 2023). Critical thinking is essential in education, particularly in biology learning (Fitriana et al., 2020). Students with strong critical thinking skills are not only able to memorize concepts but also analyze biological phenomena, evaluate scientific information, and make data-based decisions. Biology involves complex and abstract concepts that require higher-order thinking skills such as analysis, interpretation, and evaluation (Danil et al., 2023; Fitriana et al., 2020). Therefore, learning should be designed to encourage students' active involvement in the critical thinking process.

Research results indicate that university students' critical thinking skills are still low (Saenab et al., 2021). Research by Arsih et al. (2020) also indicates that prospective biology teachers' critical thinking skills are still low. Furthermore, biology learning is still dominated by conventional approaches oriented towards memorization. The learning process tends to be teacher-centered, limiting students' opportunities to develop higher-order thinking skills, actively explore, ask questions, and construct knowledge independently (Wu et al., 2025). This condition limits students' opportunities to develop higher-order thinking skills, including critical thinking. This condition contributes to students' low critical thinking skills and indicates a gap between the demands of 21st-century competencies and classroom learning practices.

One potential solution is to implement an innovative learning model that can encourage active student engagement. The Reading, Questioning, and Answering (RQA) model is an approach that emphasizes reading, formulating questions, and answering them independently (Aisya et al., 2023; Fania et al., 2021). The RQA model has been shown to motivate students to read the assigned learning material (Leasa, 2024). This model enables students to process information more deeply, potentially improving conceptual understanding and critical thinking skills.

Along with the development of educational technology, the integration of gamification elements into learning has also received increasing attention. Gamification is the application of game elements, such as points, levels, challenges, and rewards, within a learning context to increase student motivation and engagement (Conde et al, 2025; Yildiz, 2021). This approach is considered effective in creating a more engaging, interactive, and competitive learning environment (Anisa, 2020; Zeng et al., 2024). Additionally, gamification-assisted learning can improve students' academic achievement (Almufarreh, 2026).

The RQA model and gamification have been widely studied separately; however, their integration into a single instructional framework remains limited, particularly in biology learning. Research related to gamification tends to focus on increasing motivation and learning engagement, while studies aimed at developing critical thinking skills are limited. Furthermore, the implementation of the RQA model has generally not been combined with strategies that systematically increase student motivation and active participation. Thus, research is needed that applies learning models that integrate the advantages of RQA and gamification to improve students' critical thinking skills.

Based on these facts, the application of the RQA model with a gamification approach, known as the RQA-assisted gamification model, is expected to be a learning innovation that not only increases learning motivation but also optimizes students' critical thinking skills in biology learning. By combining the immersive cognitive activities of RQA with the increased engagement of gamification, this model has the potential to create a more meaningful learning experience. This study proposes an integrated learning model by integrating Reciprocal Questioning and Answering (RQA) with gamification to enhance students' critical thinking skills in biology learning. Therefore, this study aims to analyze the effect of implementing the RQA-assisted gamification model on improving students' critical thinking skills in biology learning. Theoretically, this study enriches instructional design literature by integrating cognitive and motivational learning approaches. Practically, the proposed model can be applied by biology educators as an alternative strategy to improve students' critical thinking skills. The results are expected to provide theoretical and practical contributions to the development of innovative learning strategies relevant to the demands of 21st-century education.

## 2. METHODS

This study employs a quasi-experimental design with a Pretest-Posttest One Group Design. This design was used to examine the effect of the RQA-assisted gamification model on students' critical thinking skills by comparing their performance before (pretest) and after (posttest) the treatment. The independent variable was the RQA-assisted gamification model, and the dependent variable was students' critical thinking skills, which were measured using an essay test based on five indicators: interpreting, analyzing, evaluating, concluding, and explaining, adapted from Facione (2020). The population consisted of all Biology Education students at Sultan Ageng Tirtayasa University. The sample consisted of 30 fifth-semester students (2024/2025) selected using purposive sampling. In addition, observation sheets were used to support the data. The instrument was validated by two experts in biology education to ensure content validity. The essay test was used as the main instrument for both pretest and posttest. Prior to hypothesis testing, a normality test using the Shapiro-Wilk test was conducted to determine whether the data were normally distributed. Since the data were not normally distributed, the Wilcoxon signed-rank test was applied using SPSS 25 for Windows. The N-Gain test was also carried out to determine the effectiveness of the RQA-assisted gamification model. The Normalized Gain scores were interpreted using the following criteria: high ( $\geq 0.7$ ), medium (0.3–0.7), and low ( $< 0.3$ ).

## 3. RESULTS

Descriptive analysis shows an increase in students' critical thinking ability scores after receiving the RQA-assisted gamification model, with scores ranging from 70 to 96. The N-gain score of 0.8 indicates that the model is highly effective, as shown in Figure 1.

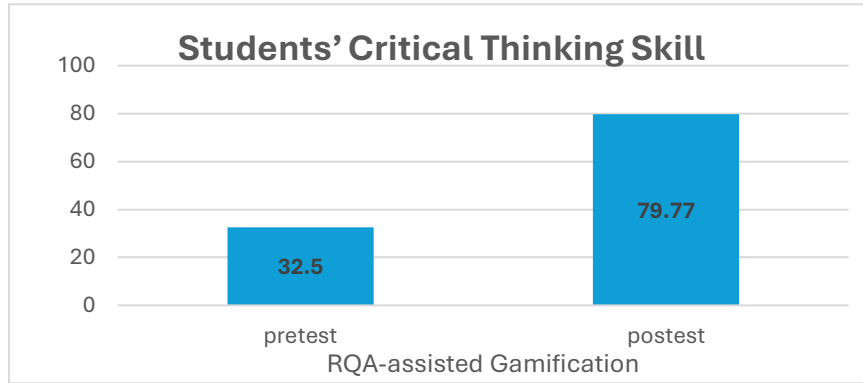


Figure 1. Average Score of Students' Critical Thinking Skill

The scores of the five critical thinking indicators that have been assessed are shown through the students' post-test scores in Figure 2 below.

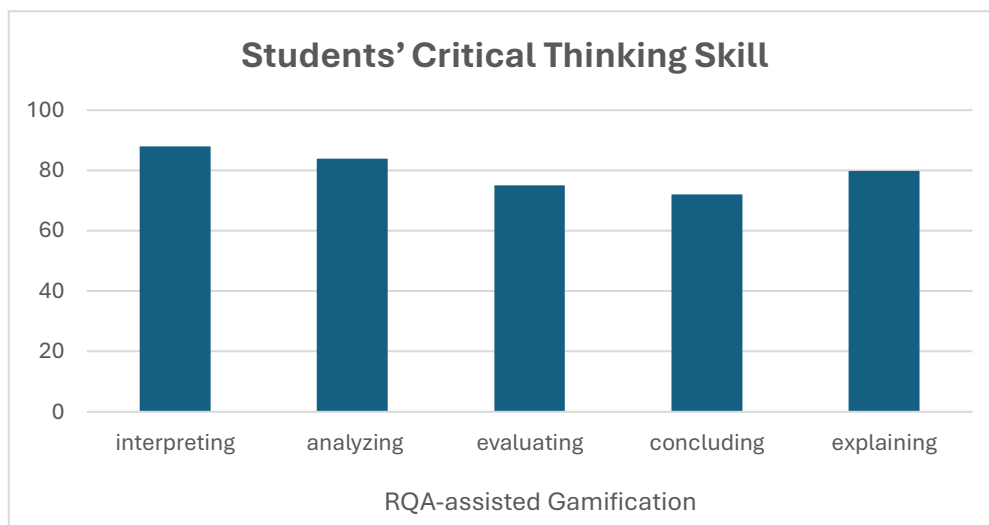


Figure 2. Students' Critical Thinking Skill Scores

Figure 2 shows that the highest score was obtained in the interpreting indicator. This finding indicates that students are able to understand and interpret situations. The lowest score was for the concluding indicator, indicating that students' ability to draw conclusions was the lowest. The results of the Wilcoxon test are presented in Table 1.

Table 1. The Results of The Wilcoxon Test on Students' Critical Thinking Skills

	AVERAGE	ST DEV.
Pre	32.5	7.32
Pos	79.77	7.37
Z table		1.960
Z calculated		-4.706
P-Value z		0.000

Table 1 shows that the average critical thinking ability score on the pretest variable is  $32.5 \pm 7.32$ , lower than the critical thinking ability score on the posttest variable, namely  $79.77 \pm 7.37$ . There is an increase in the average critical thinking ability score from pretest to posttest. To validate these results, a Wilcoxon test was conducted. The results of the Wilcoxon test show that the calculated Z value is smaller than the Z table value ( $-4.706 < -1.960$ ), and the p-value is smaller than  $\alpha$  ( $0.000 < 0.05$ ). These results provide the conclusion that  $H_0$  is rejected, which means that there is a significant difference between the pretest and posttest scores of students' critical thinking abilities.

#### 4. DISCUSSION

The results showed the highest score on the interpreting ability indicator. In this indicator, students are able to interpret meaning and understand situations, events, and experiences (Facione, 2020). Interpreting ability also showed the highest score in this study, indicating students can examine problems and filter information effectively (Wahyuningtyas & Widiyono, 2024). Through a good mastery of the interpreting indicator, students will be able to answer questions by understanding and explaining data (Aswanti & Isnaeni, 2023). Furthermore, this interpreting ability will lead students to express ideas according to their position by re-describing the meaning of information (Azis & Ibrahim, 2021).

The lowest score for students' critical thinking skills is in the concluding indicator. In this indicator, students must be able to draw conclusions to form hypotheses, extract relevant information, and deduce consequences from data (Facione, 2020). These results are consistent with previous studies showing that students' concluding skills remain low (Fahmi et al., 2025; Firiani, 2022; Widyapuraya et al., 2021). This low performance may be due to students' difficulty in identifying key elements needed to draw valid conclusions (Widyapuraya et al., 2021). This may be due to the fact that drawing conclusions in problem-solving is more cognitively demanding than other critical thinking indicators.

The results of the Wilcoxon test (Table 1) indicate that the RQA-assisted gamification model has a significant effect on students' critical thinking skills. The RQA-assisted gamification model provides meaningful learning experiences for students through various activities such as literature searching, summarizing readings, generating questions, answering questions, and engaging in group discussions through interactive games. This finding is consistent with Xu et al. (2026), who reported that instructional strategies can enhance students' thinking skills and student achievement. Furthermore, a well-planned learning model can improve students' higher-order thinking compared to conventional classes (Hasan et al., 2024). The RQA model enhances students' understanding and stimulates their curiosity through engaging reading activities and encouraging them to ask questions for critical thinking compared to conventional classes (Hariyanto et al., 2024; Rahman et al., 2020).

In addition, integrating gamification with the RQA learning model helps motivate students to structure information from general to specific. This approach fosters the development of their critical thinking abilities. Gamification can increase student motivation in class, thereby enhancing desired learning goals (Anisa et al., 2020; Yildiz et al., 2021). Through gamification, students can be motivated to focus on the topic and effectively organize the sequence of their written ideas or concepts (Dewi et al., 2025).

The improvement in critical thinking skills can be attributed to several factors. First, the questioning and answering process within the RQA model prompts students to engage in deeper cognitive processing of the subject matter, thereby fostering a more critical comprehension. Second, the implementation of gamification to motivate learning in class leads to the development of a more comprehensive and analytical understanding. The limitation of this study is that it only involved one class with a sample size of 30 students, so the generalizability of the research results to a wider population is still limited.

#### 5. CONCLUSION

The integration of gamification into the Reading, Questioning, and Answering (RQA) model significantly enhances critical thinking skills among biology education students. By transforming the traditional literacy-based model into an interactive and competitive experience, educators can reduce student passivity. Further research is needed to obtain more comprehensive findings on the impact of implementing RQA-assisted gamification on a larger research sample with the same variables. Additionally, the RQA-assisted gamification learning model offers opportunities for broader research on various subjects, larger class sizes, educational levels, and 21st-century skills.

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