RESEARCH ARTICLE

The effect of reading questioning answering integrated with creative problem solving on critical thinking

Naafi Aisya [a,1], I. Ibrohim [a,2,*], Susriyati Mahanal [a,3], Hidayati Maghfiroh [a,4]

[a] Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Jl. Semarang No. 5 Malang, East Java65145, Indonesia

[1]aisyanaafi@gmail.com; [2]ibrohim.fmipa@um.ac.id; [3]susriyati.mahanal.fmipa@um.ac.id; [4]hidayati.maghfiroh.1703416@students.um.ac.id

Abstract: Although the empowerment of critical thinking (CT) has become an international concern that needs to be developed in the biology learning process for high school students, there still needs to be more relevant research literature. This study aimed to compare the effectiveness of implementing reading, questioning, and answering strategies integrated with creative problem solving (RQA-CPS) with RQA, CPS, and discussion strategies. This method used the pretest-posttest non-equivalent control group design for one semester using four classes. We designed that the experimental group was taught with RQA-CPS, the control-I group was taught with RQA, the control-II group was taught with CPS, and the control-III group was taught with DP. This research involved 129 high school students in four classes with the topics Plantae, Animalia, Ecology and Environmental Change. These four topics are classified as complex material that requires CT to be able to understand in depth. The results showed that high school students' CT increased in all four classes, but the RQA-CPS group experienced the most significant increase and was significantly different compared to the other three control groups. Thus, the RQA-CPS strategy should be used in learning to improve students' CT.

Keywords: Cooperative learning; creative problem solving; critical thinking; high school students; reading questioning answering

For correspondence:
ibrohim.fmipa@um.ac.id

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Introduction

Critical Thinking (CT) is a global concern for science education that must be incorporated into learning (Ma et al., 2021). Vincent-Lancrin et al. (2019) described CT as four cognitive processes: asking, analyzing, formulating, and reflecting. CT is a reflective thinking skill that involves analyzing, evaluating, or synthesizing relevant information to form arguments so that students are expected to make decisions (Ennis, 1993; Ghanizadeh, 2017). Furthermore, CT is defined as a skill to identify relationships, analyze probabilities, make predictions and logical decisions, solve complex problems, and create valid conclusions, so improving CT is important (Halpern & Dunn, 2022).

Various studies have shown that students' CT can be empowered with the learning process, such as cooperative learning. One model of cooperative learning based on constructivism is reading, questioning, and answering (RQA). RQA consists of three main stages: reading, questioning, and answering. Reading empowers students to explore knowledge (Zubaidah et al., 2018). Questioning aims to trigger students to evaluate the knowledge that has been understood (Hariyadi et al., 2018). Answering facilitates students in connecting new knowledge and previous knowledge (Bustami et al., 2020).

RQA is an active learning strategy emphasizing empowering thinking through reading, questions, and answering in teaching biology (Saputri & Corebima, 2020). Activity in RQA is essential because it can familiarize students with reading learning material individually before studying in the class so they can be better prepared to learn (Hariyadi et al., 2018). The RQA strategy has several advantages, such as

facilitating students to work seriously and being involved in discussions to increase CT (Sumampouw et al., 2016). Various studies have also shown that RQA can empower critical and metacognitive thinking skills (Amin et al., 2020) and higher-order thinking skills (Amin et al., 2019). However, recent research shows the importance of teaching socio-scientific issues so that it brings the need for students to be able to think critically in dealing with real problems, which can be supported by creative problem-solving (CPS) (Kapoor et al., 2020).

CPS is a learning strategy that encourages students to think critically and creatively solve complex problems based on socio-scientific issues (Soyadı, 2015). CPS consists of four stages that can be used to foster students' CT: exploring data, generating ideas, developing solutions and building acceptance, and appraising tasks (Kapoor et al., 2020). Exploring data is the stage of students exploring by linking phenomena and the learning material (Puccio et al., 2020). Generating ideas involves students brainstorming where to group students to discuss and design projects to solve issues. Developing solutions and building acceptance is the stage where students present the results of the projects that have been made. The appraising task is the stage for students to write self-reflections and conclusions about the learning material (Chen & Ye, 2022).

Several studies have shown that CPS has advantages, such as encouraging students to build their knowledge and generate student motivation (Hu et al., 2017). CPS can create positive experiences that help students generate new ideas (Hargrove & Nietfeld, 2015). CPS is based on problem-solving, encouraging students to redefine problems, make arguments, make solutions, and take action (Maker et al., 2023). CPS can be a strategy that can provoke students to make inferences to evaluate arguments in dealing with socio-scientific issues (Barbot et al., 2016). Thus, integrating RQA and CPS is essential in optimizing students' CT, especially in complex biology material.

Biological materials categorized as complex include Plantae, Animalia, Ecology, and Environmental Change (Forestiero, 2022). The integration between RQA-CPS is expected to facilitate students can be more optimized CT to understand complex biology material critically and deeply. The designed RQA-CPS consists of seven stages: reading, questioning, answering, exploring data, developing solutions and building acceptance, and appraising tasks. Reading is the stage where students read news related to phenomena, read material from various information, and make summaries. Questioning is when students compose questions about phenomena or concepts. Answering is the stage for students to answer previously prepared questions (Zubaidah et al., 2018). Exploring data is when the teacher provokes students to brainstorm to connect between phenomena and concepts. Generating ideas is the stage where group students discuss and design projects to solve phenomena. Developing solutions and building acceptance is the stage where students present the results of the projects that have been made. The appraising task is when students write self-reflections and conclusions about the concepts from learning (Kapoor et al., 2020).

In line with the potential of RQA and CPS, several studies have focused their studies on analyzing the impact of RQA (Nuzulah & Budijastuti, 2018; Sudin et al., 2018) and CPS learning models on CT (Muzaimah et al., 2022; Zulfikar et al., 2022). Several other studies have also integrated these two learning models into the RQA-CPS learning model and analyzed their effects on students' creative thinking skills (Jauhari & Samudera, 2022; Samudera & Mariana, 2022). However, the utility of these two models is underreported and studies focusing on CT are difficult to find. Therefore, this study aims to analyze the effect of RQA-CPS on students' critical thinking skills. This study compares how different students who taught with the RQA-CPS, RQA, CPS, and discussion-presentation (DP). The research question was how did students' CT differ after learning with RQA-CPS, RQA, CPS, and DP? Quasi-experimental research is needed to answer this research statement for determining how RQA-CPS can be significant in empowering students' CT. This research project also identifies how the RQA-CPS can promote students' CT in the context of learning biology.

Method

Research design and participant

A quasi-experimental design with a pretest-posttest non-equivalent control group design was conducted in this study (Cresswell, 2012). We used this design to compare the effectiveness of the application of four learning models, namely: (1) Reading Questioning and Answering Integrated with Creative Problem Solving (RQA-CPS), (2) Reading Questioning and Answering (RQA), (3) Creative Problem Solving (CPS), (4) and discussion-presentation (DP) in improving critical thinking. Furthermore, the determination of the experimental and control classes was based on the equivalence test results, carried out by the Analysis of Variance (ANOVA) test with a value of 0.769 so that $p > 0.05$. The results of ANOVA showed that the four classes, A, B, C, and D, were used equally. Furthermore, the four learning models were evaluated for their effectiveness in increasing critical thinking by design, as follows: (1) RQA-CPS was taught in Class A as an experimental class, (2) RQA was taught in Class B as a positive control class, (3) CPS was taught in Class C as the positive control class, (4) DP taught Class D as the negative

control class. This research was conducted in class X for one semester in 2019. Participants who agreed to participate in the research were 129 students divided into four classes from the MIPA major at a private high school in East Java, Indonesia. The distribution of participants is presented in Table 1.

Table 1. Distribution of participants (n= 129)

Group	Intervention	Amount (n)
Class A	RQA-CPS	34
Class B	RQA	33
Class C	CPS	33
Class D	DP	29

Data collection procedures

Several research procedures were carried out by researchers in order to collect data following ethical research guidelines. First, the researcher asked for research permission from the headmaster of the senior high school and sent approval from potential participants. Of the 129 participants, 129 participants agreed to participate in this study. All four classes were taught by teachers with a minimum of five years of experience in Biology. The four classes were given the same biology topics: Plantae, Animalia, Ecology and Environmental Change.

Learning environment and intervention

The intervention was conducted in two sessions a week, with the duration of the first session being 45 minutes while the second session was 90 minutes. Furthermore, the four classes with the learning environment were given different interventions as follows. Class A was implemented with the RQA-CPS, which consists of several stages: (1) Reading, the stage of students reading news related to current phenomena, reading material from various information, and making summaries. (2) Questioning, the stage of students composed questions related to concepts. (3) Answering, the stage of students answering questions prepared beforehand. (4) Exploring Data, the stage the teacher invites students to brainstorm to connect phenomena and concepts. (5) Generating Ideas, the stage of students discussing and designing projects to solve phenomena in groups. (6) Developing Solutions and Building Acceptance, the stage for students to present the results of projects that have been made. (7) Appraising Task, the stages in which students write self-reflections and conclusions.

Class B was implemented with the RQA learning model, which consists of three stages: (1) Reading, the stage of students read material, information, and news related to the given phenomena and make summaries. (2) Questioning, the stage of composing questions related to concepts or material they have yet to understand. (3) Answering, the stage of students answering questions prepared beforehand. Class C was implemented with the CPS learning model, which consists of stages. (1) Exploring Data is the stage of students brainstorming and connecting phenomena with concepts. (2) Generating ideas, the stages of students discussing and designing projects in groups to solve phenomena. (3) Developing Solutions and Building Acceptance, the stages where students present the results of projects that have been made). (4) Appraising Task, the stages in which students write self-reflections and conclusions about the concepts. Class D was taught with the Discussion-Presentation learning model, which consists of two stages. (1) Discussion, the stages of students discussing the material provided. (2) Presentation, the stages of students presenting the discussion results. Furthermore, the observer observed the four classes to ensure the four learning models were appropriately implemented.

Data collection tools

Researchers have developed the CT instrument, and two Biology education experts in Indonesia have validated it to ensure the validity of the content. The results of empirical trials of critical thinking test questions on students have been tested previously, and the results were valid and reliable. The validity test using the coefficient correlation showed scores less than 0.05, meaning the test was valid. The reliability test using Cronbach's Alpha showed a score of more than 0.70., meaning the test was reliable. Determination of the score using the critical thinking skills rubric, which refers to Finken and Ennis (1993) on a scale of 0-5.

CT was measured by an essay test that refers to Ennis (2015), which has six indicators, namely: (1) interpretation is understanding issues and concepts, (2) analysis is analyzing the relationship between issues and concepts, (3) evaluation is evaluating the credibility of statements (4) explanation is formulating several credible statements (5) self-regulation is evaluating the relationship between issues and formulated statements.

Data analysis

Before statistical analysis, all data tested the normality with One-sample Kolmogorov-Smirnov and

homogeneity with Leven's Test of Equality of Error Variances with SPSS 25. The results of the assumption test for normality and homogeneity of critical thinking showed values of 0.200 and 0.475, so it shows p> 0.05. These results showed that the data is normally distributed, and the variances of the four groups are homogeneous. Furthermore, the data were analyzed using descriptive statistics with the mean (M) and inferential with the ANCOVA test. The ANCOVA test was analyzed to determine the effectiveness comparison between one experimental class and three control classes. If the ANCOVA test results are significant, then proceed with the LSD test to find out which class has the highest increase and is significantly different from the other classes.

Results and Discussion

Before implementing four learning strategies, the student's critical thinking in the four groups was almost the same, namely class A (M=75.65), class B (M=75.65), class C (M=75.65), class D (M=75.65). After implementing, the critical thinking of the four groups showed quite a big difference. Class A and C were almost the same, with each average (M=82.79) and (M=79.39). Meanwhile, the average final ability of classes B and D was far below classes A and B, with each average (M=76.57) and (M=74.79). A summary of descriptive statistics is presented in Table 2.

Table 2. The results of descriptive statistic on critical thinking

Class	Test	Mean	Minimum	Maximum
Class A	Pretest	75.65	58.26	87.79
RQA-CPS	Posttest	82.79	68.89	91.89
Class B	Pretest	72.69	59.93	86.98
RQA	Posttest	76.57	54.59	90.39
Class C	Pretest	74.94	58.64	87.99
CPS	Posttest	79.39	59.63	90.47
Class D	Pretest	71.77	58.74	82.70
DP	Posttest	74.79	54.39	90.19

The ANCOVA test proved the significant difference between the four groups. The results of the ANCOVA test (Table 3) showed a significant difference between students' critical thinking using the RQA-CPS, RQA, CPS, and the DP (F=234,488; p= 0.007). Furthermore, an LSD test was conducted to find classes that best empowered students' critical thinking. The LSD results (Table 4) showed that the RQA-CPS class was significantly different in empowering students' critical thinking compared to the RQA, CPS, and DP. The average pretest and posttest scores reinforce this; students in the RQA-CP (EM Score=80.866) were proven to be able to achieve better than students in the CPS class (EM Score= 75.953), RQA (EM Score= 75.856), and DP (EM Score=75.119). The results of the LSD test showed that the RQA-CPS learning model has great potential to improve students' critical thinking.

Table 1. ANCOVA test results on critical thinking variables

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1489.886[a]	4	372.472	6.586	0.000
Intercept	4667.355	1	4667.355	82.530	0.000
Pretest	478.606	1	478.606	8.463	0.004
Class	703.465	3	234.488	4.146	0.007
Error	8878.878	124	56.553		
Total	985858.189	129			
Corrected Total	10368.765	128			

Table 4. LSD test results on critical thinking

Model	EM Score	Notation* LSD
DP	75.119	a
RQA	75.856	a
CPS	75.953	a
RQA-CPS	80.866	b

The main objective of this research is to compare the effectiveness of implementing reading, questioning, and answering strategies integrated with creative problem-solving (RQA-CPS) and RQA, CPS, and

discussion-presentation (DP). The results of ANCOVA test showed that the research variable's students in the RQA-CPS experimental group significantly differed from the other three control groups (RQA, CPS, and DP) in empowering critical thinking. This research was conducted to overcome the gap in the literature on empirical studies by measuring the extent to which the effectiveness of implementing the RQA-CPS had yet to be reported.

The ANCOVA test results align with previous studies showing that reading stages in RQA positively affect critical thinking. Zubaidah et al. (2018) stated that reading is the most effective learning activity because students can improve critical thinking by developing new and different perspectives, understanding themselves and the world, and interpreting phenomena. Mehta and Al-Mahrooqi (2015) showed that there is a relationship between reading interest and critical thinking. Zubaidah et al., (2018) proved a positive relationship between critical thinking and reading comprehension; students with higher critical thinking show better reading comprehension. Furthermore, Dinsmore and Fryer (2023) revealed that if students with high critical thinking skills, they have the potential to understand texts even though they contain difficult words.

The results align with previous studies showing that the questioning and answering stages in RQA positively affect critical thinking. Crogman and Crogman (2018) revealed that questioning and answering affect CT because they stimulate curiosity, eliminate uncertainty, and direct people to think deeply. Haavold and Sriraman (2022) stated the importance of experiencing questioning and answering when faced with solving problems critically as a stage of simplifying complex problems into simple ones. In addition, Facione (2013) assumed that education must train students to ask questions, analyze, and evaluate ideas and values. Furthermore, Lester (2013) stated the importance of asking in-depth questions in solving problems to train students to investigate problems in depth and think before ideas are implemented. Dinsmore and Fryer (2023) also revealed the importance of looking for evidence, carefully examining reasoning and assumptions, analyzing basic concepts, and highlighting implications in solving problems. However, real critical thinkers also need to be trained in creative problem-solving (CPS) based learning strategies to deal with various socio-scientific issues currently developing critically. In addition, the findings showed that the stages of exploring data on CPS positively affect CT. Maker et al., (2023) pointed out that exploring essential data is a construct for dealing with problems by determining questions, exploring information to solve problems, evaluating solutions, and implementing solutions. Hargrove and Nietfeld (2015) described that CPS involves students in certain types of creative thinking by exploring various information.

The findings showed that the stages of generating ideas in CPS positively affect critical thinking. Furthermore, Chen and Ye (2022) argued that it is essential to understand clearly the cognitive structure of a problem situation when facing new problems in the problem-solving process. Amran et al., (2019) stated that the teacher must know CPS-based learning as a facilitator in the student learning process. The teacher's role is to foster students' attitudes to state the truth, consider the opinions of others, and show curiosity in learning (Barbot et al., 2016).

Furthermore, the stages of developing solutions and building acceptance in CPS positively affect critical thinking. Hu et al., (2017) stated that solving complex problems requires logical connections between ideas. Furthermore, Barutcu (2017) stated that after the idea generalization phase, it will be followed by a solution induction phase. Heliawati et al. (2021) revealed the phase of evaluating various important ideas to produce solutions that can be applied practically.

Moreover, the appraising task stages of CPS positively affect critical thinking. Chen and Ye (2022) showed that students must be facilitated to look for problems, identify problems, solve problems, and develop creative potential. In short, critical problem-solving primarily emphasizes various possible flexible actions before selecting or executing solutions systematically (Puccio et al., 2020).

All in all, the results of this study indicated that the RQA-CPS could be an alternative learning model that can support thinking skills in science education. RQA-CPS also can be an alternative strategy that can be used to improve critical thinking. RQA-CPS can significantly improve students' critical thinking with proper timing. In this research, RQA-CPS was implemented by involving two meetings. The first session meeting can focus on the stage of reading, questioning, and answering so that students can link between issues and essential material. The second session meeting can focus on students collecting information, generating ideas, and appraising tasks. Educators or further researchers suggested designing learning using RQA-CPS by compiling lesson plans using two meeting sessions. In line with Sainz et al. (2019) effective time management can support the learning process so students can understand complex material.

This study also showed that every stage in RQA-CPS can significantly improve critical thinking when students study complex material on Plantae, Animalia, Ecology, and Environmental Change. However, this study has several limitations: First, this study still focuses on the topics of Plantae, Animalia, Ecology, and Environmental Change. Second, this research was conducted only in senior high school students. Future research can use the RQA-CPS to empower critical thinking on many biology topics and college students. Future research can also use the RQA-CPS to empower other thinking skills. Thus, looking at the learning relationship between RQA-CPS in enhancing thinking skills or the type of literacy needed

today is essential.

Conclusion

Based on the research results, RQA-CPS can be better at improving students' critical thinking compared with RQA, CPS, and discussions-presentations. Thus, educators need to develop student's critical thinking by applying the RQA-CPS model, and educators are expected to design learning effectively and prepare lesson plans with the right time allocation. Furthermore, future research is expected to be able to investigate more deeply the influence of the RQA-CPS model in empowering other thinking skills, both in biology learning and other science learning.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Author Contributions

N. Aisya: design, analysis, and writing. **I. Ibrohim:** design, conceptualization, editing/reviewing, supervision, and writing. **S. Mahanal:** design and conceptualization. **H. Maghfiroh:** analysis and writing.

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