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# The Integration of Group Investigation and Reading, Questioning, Answering (GIRQA): An Instructional Model to Enhance Metacognition and Critical Thinking of Students in Science Classroom

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## Abstract

Metacognition and critical thinking have become essential variables in science teaching. However, the low level of students' metacognition and critical thinking at various educational levels in Indonesia is still widely reported. Therefore, the GIRQA instructional model is needed to minimize the recurring gap. This study aims to determine the effect of implementing GIRQA on the students' Metacognition Awareness (MA) and Critical Thinking Skills (CTS) in Biology. This quasi-experimental study used a non-randomized control-group pre-test and post-test design. The populations were 214 students from the 10th-grade Science Program at one of the high schools in Jombang Regency, East Java, Indonesia. We used a cluster random sampling design to assign two groups (72 students) as the research samples. The instrument for measuring MA was the metacognition awareness inventory. Then, an integrated essay test was used to measure CTS. The results showed differences in metacognition awareness and critical thinking skills between students taught with the GIRQA and traditional learning models. The GIRQA contributed 48.1% to students' MA and 41.4% to students' CTS. Future research shall explore the relationship between metacognition and critical thinking using several instructional models.

**Keywords:** Metacognition awareness, critical thinking, GIRQA instructional model.

## Introduction

Developing students' metacognition and critical thinking in the 21st century is very important (Ma & Luo, 2021; McKendree & Washburn, 2021). Metacognition is associated with students' capacity to comprehend, cultivate, and regulate awareness of their cognitive processes for optimal performance (Biasutti & Frate, 2018). In addition, metacognition includes distinguishing different cognitive tasks and techniques by practicing effective planning, offering alternative solutions, analyzing, synthesizing, and assessing the process whenever a problem arises (Tosun & Senocak, 2013).

Metacognition is essential in learning, so it needs to be empowered (Dori, Mevarech, & Baker, 2018). The critical role of metacognition in learning relates to two crucial things: metacognition can establish cognitive representations based on the monitoring process and control cognition based on cognitive representations (Efklides, 2006). Students with strong metacognition will be more efficient during learning activities because they know how to use appropriate problem-solving strategies (Schraw, Crippen, & Hartley, 2006). Therefore, metacognition is one of the essential and positive predictors of students' academic success. Metacognition has also contributed to critical thinking (Magno, 2010).

Critical thinking is an intellectual process that is active and skilled in interpreting, analyzing, evaluating, inferring, explaining, and self-regulating (Facione, 2013). As an intellectual discipline process, critical thinking focuses on decision-making as a consequence of logical and reflective thinking (Ennis, 2011; Karakoc, 2016)one is helped by the employment of a set of critical thinking dispositions and abilities that I shall outline. These can serve as a set of comprehensive goals for a critical thinking curriculum and its assessment. Usefulness in curriculum decisions, teaching, and assessment, not elegance or mutual exclusiveness, is the purpose of this outline. For the sake of brevity, clarification in the form of examples, qualifications, and more detail, including more criteria, are omitted, but can be found in sources listed

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below, but most fully in my Critical Thinking (1996a. A person's capacity to employ higher-order cognitive skills (i.e., conceptualization, analysis, assessment) and attitudes (i.e., curiosity, open mind, caution in decision-making) that lead to rational action are also referred to as critical thinking (Papp et al., 2014)diagnose, and care for patients. Defined as the ability to apply higher-order cognitive skills (conceptualization, analysis, evaluation.

Critical thinking is important to be empowered in learning (Fausan, Susilo, Gofur, Sueb, & Yusop, 2021; Phan, 2010) because critical thinking is one of the essential skills (Fuad, Zubaidah, Mahanal, & Suarsini, 2017)differentiated science inquiry model, and conventional model, (2 that plays an essential role in student learning success (Halpern et al., 2012). Empowering critical thinking in the classroom can facilitate students to become individuals who tend to have good focus, provide logical reasons, perform a comprehensive analysis to make conclusions, and solve problems appropriately (Ulger, 2018). In addition, students who think critically are proven to solve the given problem because they first analyze it thoroughly before determining the right solution (Marin & Halpern, 2011).

However, the reality is that students' metacognition and critical thinking at various levels of education in Indonesia are still low. This fact was revealed in several previous study reports (Elisanti, Sajidan, & Prayitno, 2018; Fauzi & Sa'diyah, 2019; Saputri, Sajidan, & Rinanto, 2018; Setiawati & Corebima, 2018)which is the implementation in Indonesian schools is still being questioned. The present quantitative study aimed at gathering information on the profile of students' metacognitive skills in Malang and figuring out whether the students' grader influence metacognitive skills or not. This study was in ex post facto research which involves five levels of independent variables (grade level. The main problem of students' low metacognition and critical thinking in the science classroom cannot be separated from traditional learning practices. Traditional learning, from our perspective, is interpreted as dominant learning focused on lectures and expository activities. Such learning resulted in a low level of student involvement and a lack of training on student learning independence, so students' metacognition and critical thinking are not optimally empowered (Boleng, Lumowa, Palenewen, & Corebima, 2017; Pantiwati & Husamah, 2017)University of Muhammadiyah Malang; while the samples were all members of the population taken by means of saturation sampling technique. The technique of data collection was by means of Schraw and Dennison MAI (Metacognition Awareness Instrument. Therefore, to minimize the gap between reality and expectations of metacognition and critical thinking, it is necessary to design and implement an innovative instructional model as an alternative solution.

The suitable instructional model to empower students' metacognition and critical thinking in science class is an instructional model with a constructivist paradigm, such as Group Investigation (GI). GI is an instructional model that facilitates students to investigate in small groups to find problems, analyze, and solve problems democratically. In GI, each small group prepares a research study plan on a learning topic assigned by the teacher, implements the plan and collects data, uses the information gathered to solve problems, synthesizes the existing information, and presents the results (Zorlu & Sezek, 2020).

Previous studies have reported that students in science programs taught using the GI model improved their metacognition and critical thinking (Budiman & Marianti, 2020; Hikmawati, Munir, & Parakkasi, 2020). GI also reported having several advantages, including GI allows students to be directly involved in the process of acquiring new knowledge (Mitchell, Montgomery, Holder, & Stuart, 2008), and each group member has a role and responsibility during the implementation of GI (Baki, Yıldız, Aydın, & Köğce, 2010). However, from another point of view, GI also has substantial weaknesses, including: (1) the experience of authors who have previously implemented GI, finding situations and conditions where students have difficulty identifying the topic or sub-topic of the fundamental problem, this is caused by the low reading literacy of students, and (2) students with low academic abilities have difficulty collecting various investigative data (Mitchell et al., 2008).

GI has the potential to be powerful cooperative learning through development or integration (Mitchell et al., 2008). Based on this statement, the authors considered needing to integrate GI with other instructional models, which are expected to overcome the substantial weaknesses of GI. For example, Reading, Questioning, and Answering (RQA) is a potential instructional model.

RQA is an instructional model with three learning phases: reading, questioning, and answering. RQA was developed because students have a low reading interest (Corebima, 2009). Through the RQA, students are asked to study and comprehend the reading's content before locating the substantial portion. According to Corebima (2009), RQA could "push" the students to read designated learning materials to improve their comprehension. RQA is also reported to improve students' metacognition and critical thinking skills in the science classroom (Amin, Corebima, Zubaidah, & Mahanal, 2020; Rahman, Herna, Pujiastuti, & Fausan, 2020)ADI, RQA integrated with ADI are constructivistic learning strategies that can accommodate these skills. The researches specifically examining the correlation between metacognitive skills and critical thinking skills at the implementation of RQA, ADI, and RQA integrated with ADI learning strategies are still rarely found. This research is a correlational research, aiming at revealing the correlation between metacognitive skills and critical thinking skills. The data of metacognitive skills and critical thinking skills are collected by using a valid and reliable essay test. The samples of this research are the fourth semester (IV.

The integration of GI and RQA called GIRQA is an instructional model designed to provide a more meaningful science learning experience to students through activities: identifying sub-topic, planning the investigation, reading learning materials, asking questions, answering questions, presenting assignments, conducting an investigation, preparing the presentation, present the results of an investigation, and evaluate. These activities can help students understand their lives, teach scientific concepts, provide scientific experiences, and increase positive attitudes toward their environment for learning biology. Learning steps in GIRQA are also expected to empower students' metacognition awareness and critical thinking skills in learning biology.

This study aims to determine the effect of implementing the GIRQA instructional model on students' metacognition awareness and critical thinking skills in Biology. The research questions proposed to guide this research are: (1) Does the metacognitionawareness differ between students taught with GIRQA instructional model and the traditional learning model? (2) Does the critical thinking skills differ between students taught with GIRQA instructional model and the traditional learning model? It is hypothesized in this study that there are differences in metacognition awareness and critical thinking skills between students taught with GIRQA instructional model and the traditional learning model.

## Method

### Research Design

This study is quasi-experimental, applying a non-randomized pre-test and post-test design with a control group (Leedy & Ormrod, 2019). In the experimental and control groups, we conducted a pre-test at the beginning and a post-test at the end of the lesson. During their learning activities, we implemented the GIRQA instructional model for the experimental group and the traditional learning model for the control group. The design of this study is presented in detail in Table 1.

### Population and Sample

This research was conducted during the second semester of the 2019/2020 Curriculum Year. The population in this study consisted of 214 students from the 10th-grade Science Program at one of the high schools in Jombang Regency, East Java, Indonesia. Furthermore, we used a cluster random sampling design to assign two groups (72 students) as the research samples; all these students had completed an informed consent as ethical approval to follow this research. We also conducted a group equivalence test before treatment to ensure that the experimental and control groups had the same equality. The results of the group equivalence test by using Analysis of Variance (ANOVA) showed a P-value of 0.179 > 0.05; this means that both groups (experimental and control) have the same equality.

### Data Collection Tools

In this study, the instrument we used to measure students' metacognition awareness was the Metacognition Awareness Inventory (MAI) presented by Schraw & Dennison (1994). The MAI feature can identify and inventory the metacognition of adolescent and adult students. MAI consists of two components, namely metacognition knowledge and regulation, as well as eight sub-components, namely: (1) declarative knowledge, (2) procedural knowledge, (3) conditional knowledge, (4) planning, (5) information management, (6) monitoring strategies, (7) debugging strategies, and (8) evaluation. The number of MAI statements used in this study was 50, with true and false choices.

The instrument used to measure students' critical thinking skills was an eight-question integrated critical thinking essay test. Essay questions were chosen since they are open-ended; thus, they are more comprehensive in measuring students' critical thinking skills. On the other hand, it was easier for us to modify the questions according to Bloom's taxonomy. The questions used in this study have passed the validity test using the Pearson product-moment correlation and the item reliability test using Cronbach's Alpha; as a result, all items were valid (the mean item validity was 0.556) and reliable (the reliability was 0.680). Five aspects of critical thinking skills are assessed: focus, supporting reasons, organization, conventions, and integration (Ennis, 2011; Finken & Ennis, 1993)”title”:”Illinois critical thinking essay test”,”type”:”report”},”uris”:[“http://www.mendeley.com/documents/?uuid=73a2151e-fc70-4690-ba22-bd67f77aceff”]},{“id”:”ITEM-2”,”itemData”:{“abstract”:”Critical thinking is reasonable and reflective thinking focused on deciding what to believe or do. This definition I believe captures the core of the way the term is used in the critical thinking movement. In deciding what to believe or do, one is helped by the employment of a set of critical thinking dispositions

**Table 1:** Research design

| *Group* | *Pre-test* | *Treatment* | *Post-test* |
|---|---|---|---|
| Experimental | O1 (pre-test score) | GIRQA instructional model | O2 (post-test score) |
| Control | O3 (pre-test score) | Traditional learning model | O4 (post-test score) |

and abilities that I shall outline. These can serve as a set of comprehensive goals for a critical thinking curriculum and its assessment. Usefulness in curriculum decisions, teaching, and assessment, not elegance or mutual exclusiveness, is the purpose of this outline. For the sake of brevity, clarification in the form of examples, qualifications, and more detail, including more criteria, are omitted, but can be found in sources listed below, but most fully in my Critical Thinking (1996a. The scoring for critical thinking skills was guided by Zubaidah, Corebima, & Mistianah's (2015) rubric, which has a 0-5 score range. For example, each student's answer gets a five score if: (a) The concepts are precise, well-defined, and specific, (b) all answers' descriptions are precise, well-defined, and specific, supported by great reasons, logical reasons, convincing arguments, (c) good thinking, the concepts are integrated and related, (d) grammar is excellent and correct, and (e) The aspects are visible, the evidence is sound and well-balanced.

### Research Procedures

During the Coronavirus outbreak, biology learning on environmental change was conducted for ten meetings in a hybrid learning (google classroom and face-to-face in the classroom). Following the research design that has been made, we divided the students into two groups (i.e., experimental and control groups). Furthermore, each group was given a metacognition awareness pre-test using the MAI instrument and a critical thinking skill pre-test using an integrated critical thinking essay. Students in each group were given 90 minutes to complete both instruments (carried out in online mode).

We performed different treatments in each group based on the study design. During the treatment activities, the GIRQA learning steps were implemented in the experimental group, and traditional learning steps in the control group (are presented in Table 6).

The final procedure in this research was the post-test (which was given at the last meeting). Like the pre-test activity, metacognition awareness still used the MAI instrument, and the critical thinking skill still used the integrated critical thinking essay test. Students in each group were also given 90 minutes to complete the two instruments.

### Data Analysis

The score of students' metacognition awareness and critical thinking skills in the pre-test and post-test activities was calculated with the following formula: the acquisition score was divided by the highest score and multiplied by one hundred. Descriptive and inferential statistics were used to analyze the collected data. The hypothesis test used in this study was the Analysis of Covariance (ANCOVA) using SPSS version 25. Before testing the hypothesis, the prerequisite tests were first performed (i.e., normality and homogeneity). Kolmogorov-Smirnov tested the normality, and Levene tested the homogeneity. In the normality and homogeneity test, if the P-value > 0.05, the data was deemed normal and representative of a population with the same variance. In hypothesis testing, if the P-value < 0.05, the null hypothesis is rejected, and the alternative hypothesis is accepted.

## Findings

### The Students' Metacognition Awareness

This first section presents descriptive data related to the metacognition awareness of students taught with the GIRQA instructional model (experimental group) and traditional learning model (control group). Descriptive data are presented in Table 2.

Table 2 shows that although the students' metacognition awareness pre-test mean was not far apart between the two groups; the post-test mean was 9.56 points apart. The post-test mean on metacognition awareness of students taught with the GIRQA instructional model was superior to those taught with the traditional learning model. Furthermore, before testing the hypothesis, the main prerequisite tests (i.e., normality and homogeneity) were first tested.

The normality test results showed that the P-value of the metacognition awareness pre-test of students in the experimental and control groups was 0.169 > 0.05 and 0.096 > 0.05. The P-value of the metacognition awareness post-test of students in the experimental and control groups was 0.097 > 0.05 and 0.134 > 0.05. The test results indicate that the data in both groups were normally distributed.

The homogeneity test results of the metacognition awareness pre-test and post-test showed a P-value of 0.220 > 0.05 and a P-value of 0.457 > 0.05. Therefore, based on the test results, it is found that the pre-test and post-test variables of students' metacognition awareness in the experimental and control groups are homogeneous. Since the prerequisite tests were fulfilled, the hypothesis was tested using ANCOVA (Table 3).

**Table 2:** Descriptive data of students' metacognition awareness in the experimental and control groups

| *Groups* | *N* | *Mean* | *Std. Deviation* | *Std. Error* | *Min* | *Max* |
|---|---|---|---|---|---|---|
| Metacognition pre-test (experimental group) | 36 | 67.78 | 5.254 | 0.876 | 58 | 78 |
| Metacognition pre-test (control group) | 36 | 64.83 | 6.439 | 1.073 | 54 | 78 |
| Metacognition post-test (experimental group) | 36 | 85.50 | 8.436 | 1.406 | 68 | 98 |
| Metacognition post-test (control group) | 36 | 75.94 | 8.287 | 1.381 | 60 | 92 |

**Table 3:** Results of the students' metacognition awareness hypothesis testing

| Source | Type III Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 3145.927a | 2 | 1572.963 | 31.992 | .000 |
| Intercept | 441.614 | 1 | 441.614 | 8.982 | .004 |
| Pretest_Metacognition | 1502.371 | 1 | 1502.371 | 30.557 | .000 |
| Groups | 884.888 | 1 | 884.888 | 17.998 | .000 |
| Error | 3392.518 | 69 | 49.167 | | |
| Total | 475696.000 | 72 | | | |
| Corrected Total | 6538.444 | 71 | | | |

*a. R Squared = .481 (Adjusted R Squared = .466)*

**Table 4:** Descriptive data of students' critical thinking skills in the experimental and control groups

| Groups | N | Mean | Std. Deviation | Std. Error | Min | Max |
|---|---|---|---|---|---|---|
| Critical thinking pre-test (experimental group) | 36 | 49.79 | 9.512 | 1.585 | 30 | 70 |
| Critical thinking pre-test (control group) | 36 | 52.50 | 9.691 | 1.615 | 35 | 70 |
| Critical thinking post-test (experimental group) | 36 | 80.13 | 9.963 | 1.660 | 55 | 95 |
| Critical thinking post-test (control group) | 36 | 70.48 | 11.193 | 1.865 | 50 | 87.50 |

The results of hypothesis testing using ANCOVA based on Table 3 show that the P-value groups are 0.000 < 0.05. These results indicate that the null hypothesis in this study is rejected, and the alternative hypothesis is accepted. Therefore, there are differences in metacognition awareness between students taught with GIRQA instructional and traditional learning models.

### The Students' Critical Thinking Skills

Descriptive data on students' critical thinking skills with GIRQA instructional and traditional learning models are presented in Table 4.

Table 4 shows that the average critical thinking skills pre-test of students in the control group was slightly higher than the experimental group. However, the critical thinking skills post-test in the experimental group was superior compared to the control group after they were taught with GIRQA instructional model. The difference in the two groups' critical thinking skills post-test mean was 9.65 points. Furthermore, before testing the hypothesis, the main prerequisite tests (i.e., normality and homogeneity) were first tested.

The normality test results showed that the P-value of the critical thinking skills pre-test of students in the experimental and control groups was 0.081 > 0.05 and 0.154 > 0.05. The P-value of the critical thinking skills post-test of students in the experimental and control groups was 0.106 > 0.05 and 0.152 > 0.05. The test results indicate that the data in both groups were normally distributed.

The homogeneity test results of the critical thinking skills pre-test and post-test showed a P-value of 0.745 > 0.05 and a P-value of 0.472 > 0.05. Therefore, based on the test results, it is found that the pre-test and post-test variables of students' critical thinking skills in the experimental and control groups are homogeneous. Since the prerequisite tests were fulfilled, the hypothesis was tested using ANCOVA (Table 5).

The hypothesis test results using ANCOVA based on Table 5 shows the P-value groups of 0.000 < 0.05. These results indicate that the alternative hypothesis is accepted in this study, and the null hypothesis is rejected. Therefore, there are differences in critical thinking skills between students taught with GIRQA instructional and traditional learning models.

## Discussion

The results of the descriptive analysis in this study showed that students' metacognition awareness and critical thinking skills in the experimental group were superior compared to the control group. Furthermore, the ANCOVA test results showed differences in metacognition awareness and critical thinking skills between students taught with GIRQA instructional and traditional learning models. This study's results align with previous studies which reported that the integration of learning strategies significantly affected the students' metacognition (Listiana, Susilo, Suwono, & Suarsini, 2016), and could stimulate and encourage students to think critically through the use of arguments, problems, conclusion practice, and evaluations (Asyari, Al Muhdhar, Susilo, & Ibrohim, 2016).

The contribution of the GIRQA instructional model effect on the students' metacognition awareness in biology class was relatively high, namely 0.481 or 48.1% (confirmed by R squared in Table 3). Moreover, the contribution of the GIRQA instructional model effect on the students' critical thinking skills was 0.414 or 41.4% (confirmed by R squared in Table 5). The remaining percentage was 51.9%, where 58.6% was affected by other variables that this study may not measure. This contribution could be realized because the GIRQA instructional model is a cooperative learning that emphasizes participation and collaborative activities between students in small groups to achieve common goals.

The GIRQA instructional model with ten learning steps has effectively empowered students' metacognition awareness and critical thinking skills in the biology classroom. The learning steps of GIRQA and traditional learning models are briefly presented in Table 6.

The GIRQA's *first step* was identifying sub-topics. We directed students to identify sub-topics of biology learning that must be investigated. For example, some students highlighted a large amount of organic and inorganic waste in their environment, which tends to cause environmental issues since the waste was not properly managed. The activity of identifying the investigation sub-topics was the starting point for empowering students' metacognition knowledge, especially declarative knowledge. Declarative knowledge consists of factual information that an individual knows and can express orally or in writing (Ben-David & Orion, 2013). In identifying the investigation sub-topic, students were also in a situation requiring them to focus on important and relevant investigation sub-topics. Focus is one critical thinking component (Ennis, 2011)one is helped by the employment of a set of critical thinking dispositions and abilities that I shall outline. These can serve as a set of comprehensive goals for a critical thinking curriculum and its assessment. Usefulness in curriculum decisions, teaching, and assessment, not elegance or mutual exclusiveness, is the purpose of this outline. For the sake of brevity, clarification in the form of examples, qualifications, and more detail, including more criteria, are omitted, but can be found in sources listed below, but most fully in my Critical Thinking (1996a; thus, in such situations, students must think critically to determine the best investigation sub-topic.

**Table 5:** Results of the students' critical thinking skills hypothesis testing

| Source | Type III Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 3945.072a | 2 | 1972.536 | 24.341 | .000 |
| Intercept | 4830.151 | 1 | 4830.151 | 59.603 | .000 |
| Pretest_Metacognition | 2267.901 | 1 | 2267.901 | 27.986 | .000 |
| Groups | 2235.697 | 1 | 2235.697 | 27.588 | .000 |
| Error | 5591.647 | 69 | 81.038 | | |
| Total | 417918.750 | 72 | | | |
| Corrected Total | 9536.719 | 71 | | | |

*a. R Squared = .414 (Adjusted R Squared = .397)*

**Table 6:** The learning steps of GIRQA and traditional learning

| *GIRQA Instructional Model* | *Learning Activities* |
|---|---|
| Identifying sub-topics | The teacher and students determine the sub-topics and form investigative groups. |
| Planning an investigation | Students plan work procedures and divide tasks into groups. |
| Reading | Students read the assigned learning materials. |
| Questioning | Students generate substantial questions related to the materials they read. |
| Answering | Students answer the questions they prepared. |
| Presenting assignments | Students present the questions and answers they made, conduct class discussions, and submit assignments. |
| Conducting an investigation | Students conduct investigative activities according to the planned sub-topic. |
| Preparing a presentation | Students plan activities to present their findings. |
| Presenting the investigation results | Each group collect investigative report and present the results of their investigation. |
| Evaluating | The teacher assesses the investigative project report of each group. |
| Traditional Learning Model | Learning Activities |
| Preparation | Students prepare to receive biology subject materials. |
| Presentation | Students pay attention to biology subject materials delivered orally by the teacher. |
| Discussion | Students try to do discussion as well as question and answer. |
| Summing up | Students pay attention to the conclusion of biology subject materials delivered orally by the teacher. |
| Assignment | Students work on written assignments given by the teacher. |

*The second step was* planning the investigation. At this stage, each small group followed up on the investigation sub-topics that were listed previously. In planning the investigation, each small group was assigned to think of a realistic plan for collecting investigative data. During the learning activities, we observed each group because they had a unique investigative plan. This activity is good for developing students' metacognition components, especially procedural knowledge (i.e., using practical methods or procedures in conducting activities (Ben-David & Orion, 2013)) and planning. Planning and critical thinking are also reported to be proportional because planning requires a thorough internal debate about the achievement of goals optimistically and the appropriate method to achieve them (Holder & Jordan, 2019).

*The third step* was reading. At this stage, each student was assigned to read material related to his/her investigation sub-topics at home to obtain more information. This activity is essential because reading at this stage requires complex cognitive abilities that integrate text information with the readers' knowledge to produce the elaboration. While reading, students slowly develop the skills of assessing and deeply interpreting the text, analyzing, evaluating, and finally reflecting on it. Aloqaili (2012) reported a significant correlation between reading comprehension and critical thinking. Furthermore, the results in this study revealed that after students were assigned to read, they were more courageous and enthusiastic in providing supporting reasons (one of the critical thinking components) related to their investigation sub-topics. This finding is in line with previous research, which reported that reading activities are beneficial in improving students' critical thinking skills (Rani, 2016).

The *fourth step* was questioning. Students generated substantial questions during and after they read. Each student reported that they could ask three to four questions during and after the reading activity. We appreciated the effort, although some students' questions were not yet substantial. However, they have the self-efficacy to recreate substantial questions. Reading-generated questions could make the students think using metacognition knowledge (Santoso & Yuanita, 2017). Questioning can be implemented to direct students' attention to specific information and encourage them to code certain connections. When students generate questions, they first identify important information to provide the substance of the question, then present such information in the form of questions and self-tests to ensure that they can answer their questions. Santoso, Yuanita, & Erman (2018) reported that critical thinking is closely related to students' ability to generate questions.

*The fifth step was* answering. After students generated questions, they were assigned to answer their questions. Students have their way of presenting the answers to the questions. It all depended on the content of the substantial questions they generated. Answering their questions was intended to help students deepen their understanding (Castells et al., 2022). Because in order to answer these questions, students must construct a situation model in which they select and relate information dispersed throughout the text, as well as integrate prior knowledge with text-based information. Answering questions could also develop information management (one of the metacognition components), namely the skills and strategy sequences used more efficiently to process information (Ben-David & Orion, 2013; Schraw & Dennison, 1994).

*The sixth step was* presenting assignments. Each student selected for the presentation was given 15 minutes. This activity allowed students to briefly and concisely present the important points of the questions and answers they made to their colleagues. We observed that students› presentation activities were able to transfer information and affect the whole class. Presenting assignments in this study could empower the students' metacognition components, especially declarative knowledge. This finding is in line with Khoshsima & Rezaeiantiyar (2014), which reported that presentation strategies are helpful for students because they help students see the strengths and weaknesses of specific reading passages and consider how to improve them.

*The seventh step was* conducting investigations. In groups, students carried out investigations according to the planned sub-topics. Each group arranged its investigation schedule and reported to the teacher any obstacles they experienced during the investigation. We still controlled the investigation of each group through class groups on WhatsApp. When students conducted investigations, they analyzed data, discussed, and analyzed their findings. This activity empowers critical thinking skills, especially organizing, develops students' metacognition, especially conditional knowledge (i.e., knowledge related to when and why to use specific procedures, skills, or strategies (Ben-David & Orion, 2013)), and debugging strategies to complete the given task. This finding is in line with previous research, which reported a simultaneous investigation effect on problem-solving skills and students' achievement (Aini, 2020)(2. Therefore, the investigation can establish situations where students interact with the environments while working collaboratively in a cooperative climate to investigate problems (Tsoi, Goh, & Chia, 2004).

*The eighth and ninth steps*: preparing a presentation and presenting the investigation results. Each selected group prepared a presentation of the results from their investigation findings. Each group was free to present their investigation findings through PowerPoint slides or images, which was clear for each group to collect reports on their investigation results. Each group obtained 15 minutes to present their investigation findings, and the non-presenting group was given the foremost opportunity to respond to the presenting group. In this study, presenting investigation results is suitable for training students to communicate effectively, express their opinions, debate, and be responsible for the presentation because it was based on data or evidence based on the investigation results. Presenting investigation results that begin with preparing a presentation can develop metacognition, especially conditional knowledge and monitoring strategies (assessment on the use of one's strategy (Schraw & Dennison, 1994)) and critical thinking, especially conventions (i.e., controlling the use of correct grammar). Furthermore, there is an agreement between the findings of this study and Robillos' (2022) statement that oral presentations are important in obtaining information, academic experience, student involvement, and assessing student performance in class.

*The tenth step was* evaluating. At this last stage, we facilitated each group to integrate the findings and conclusions of their investigation in order to build new knowledge. At this stage, we also assessed the investigation project report for each group and provided rewards to the group with the best performance. In this last stage, students› metacognition, especially evaluation, developed well because students were able to reveal the performance and effectiveness of the strategies used after the investigation. Activities at this stage were in sync with the statement that evaluation critically examines an activity by collecting and analyzing information about activities, characteristics, and results (Patton, 2002). It was to ensure students' comprehensive development, making positive changes in concepts, habits, tendencies, interests, and skills (Alelaimat, Al-Dababneh, & Al-Zboon, 2020).

The stages of the GIRQA instructional model in biology learning have positively impacted students' metacognition awareness and critical thinking skills. Students' metacognition awareness and critical thinking skills are the principal capital in learning biology. Metacognition and critical thinking contribute positively to developing logical reasoning, scientific inquiry skills, and understanding of biological concepts, which certainly impact excellent student academic achievement. The implementation and implications of GIRQA are not limited to biology classrooms but can also be applied to other science classrooms, such as physics and chemistry. It can be realized because the manifestation of the GIRQA instructional model is classroom collaboration learning based on scientific investigations as meaningful learning with open-ended activities.

## Conclusion and Suggestion

There are differences in metacognition awareness and critical thinking skills between students taught with GIRQA instructional and traditional learning models. The post-test mean of students' metacognition awareness and critical thinking skills in the experimental group that applied the GIRQA was superior to the control group that applied the traditional learning model. The reason was that each stage of the GIRQA instructional model supports and facilitates the development of metacognition and critical thinking, as discussed in the discussion segment. Furthermore, the contribution of the GIRQA on the students' metacognition awareness was 48.1%, while the contribution of the GIRQA on the students' critical thinking skills was 41.4%.

We suggest that future researchers explore the correlation between students' metacognition and critical thinking using several different instructional models, and GIRQA is included as one of the variables. It seems interesting because it will show the GIRQA position compared with other instructional models after the regression test. From another point of view, research exploring the correlation between dependent variables by comparing several different instructional models is still underreported.

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