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Learning Biology through Thinking Empowerment by Questioning: The Effect on Conceptual Knowledge and Critical Thinking

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Research on active learning that emphasises question formulation activities has received less attention. This study was conducted to address the said gap identified in the literature by testing the thinking empowerment by questioning (TEQ) strategy on the level of conceptual understanding (CK) and critical thinking (CT) of students in Biology subjects. We used a pre-test-post-test non-equivalent control group design with a sample of junior high school students (n = 176). Participants were divided into three groups, namely (1) the TEQ group, 61 students; (2) PS (problem-solving) group, 60 students; and (3) the CS (conventional strategy) group, 55 students. We also considered the effect of school type (public and religious) on student performance in each treatment group and identified a potential correlation between CK and CT. Statistical results showed that TEQ had a more effective and significant effect on students' CK and CT than in the two control groups. However, we identified no difference between students in public and religious schools in each treatment group. In addition, this study also found a strong correlation between CK and CT through the implementation of TEQ.

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Finally, TEQ is an effective active learning strategy that promotes students' critical thinking in science content and is equally effective when administered to public and religious schools.

Introduction

One of the most crucial science learning activities is students' Critical Thinking (CT) skills (Bailin, 2002). CT is considered essential in improving the overall quality of education (Davies, 2013; Kavenuke et al., 2020) and stimulating the improvement of students' academic achievement (Hohmann & Grillo, 2014). However, there is a concern that science teachers often face, namely the process of promoting student CT. Previous research proved that CT is difficult to encourage in science teaching (Willingham, 2008). This question becomes more interesting when focusing on several earlier works, such as that of Vincent-Lancrin (2021), about designing lessons to give students plenty of room to develop CT.

CT has been included as a core skill in formal school curricula in many countries (Thomas & Lok, 2015). The perspective of CT in education is derived from the theory proposed by Ennis (1989) and McPeck (1990). Both of them have different definitions and views. Ennis (1989) emphasises that CT is a general thinking skill separate from the subject. Otherwise, McPeck (1990) argues that critical thinking is always related to content. According to the curriculum objectives in Indonesia, junior high school students must "have the ability to think critically through a scientific approach following what is learned in education units and other sources independently." In the syllabus, CT is interpreted and operationalised in specific ways in various subjects. Hyytinen, Toom, and Postareff (2018) explain that all aspects of critical thinking need to be developed in all disciplines.

In keeping with these demands, this study attempts to provide an intermediary between the debates of Ennis (1989) and McPeck (1990). Nygren et al. (2019) find that disciplines may have different dimensions of critical thinking. Even Ennis is said to have the perspective that CT as a general skill will vary across various disciplines. CT is often linked to a disciplinary context (Morris, 2017). Thus, CT in this study was formulated as a general ability and more specific way related to science learning in junior high schools.

By these findings, teachers need to pay great attention to the development of students' CT during learning (Shaw et al., 2020). Students' CT can be developed by involving them in learning processes relevant to real-life (Putra et al., 2021). Teachers can also choose learning that encourages students to decide on a problem (Ghanizadeh, 2017). In other words, an active approach needs to be applied to create a class that involves more students (Fiksl et al., 2017) to provide a learning experience that leads to the development of higher-order thinking (Vlaardingerbroek et al., 2017).

In this study, we tested one of active learning, Thinking Empowerment by Questioning (TEQ). TEQ is an active learning strategy that emphasises empowering thinking through questions in biological teaching (Amin et al., 2019; Hariyadi et al., 2018; Kristiani et al., 2015; Saputri & Corebima, 2020). In this strategy, students work earnestly to engage in the given questions, improve CT (Thompson, 2018), and encourage students to construct knowledge (Aguilera & Perales-Palacios, 2020). TEQ maximises and enhances the tools of active learning strategies such as Problem Based Learning (PBL) and Problem Solving (PS). Questions become a crucial starting point and determine the direction of the investigation, analysis, and identification of solutions in this strategy (Dolmans et al., 2016; Funke, 2014; Md Zabit, 2010). However, teachers and students often fail to ask questions (Abushkin et al., 2018; De Witte & Rogge, 2012), which can cause students to be unable to engage critically in discussions (Zhang et al., 2010). This finding strongly emphasises that the question formulation activity should concern all active learning.

The study of the moderating variables of critical thinking agrees that conceptual knowledge (CK) is a determining factor in improving students' CT. The CK quality of science can facilitate more effective and objective CT (Cottrell, 2011; McPeck, 1990; Yu et al., 2015). It was confirmed by McClune and Jarman's (2010) research that the critical element that supports critical reading is knowledge and thinking skills, where scientific knowledge is considered the main factor. Other studies also show that it is almost impossible to react critically without good conceptual mastery in a relevant field (Viennot & Décamp, 2020). In summary, we are interested in the fact that there is a correlation between CK and CT with applying specific learning methods, as reported by previous studies (Suwono et al., 2021; Wulandari, 2018).

In the context of research, secondary schools in Indonesia are divided into two types of schools under two ministries: general (the ministry of education and culture and higher education) and Islamic religion (the ministry of religion). The second school is often criticised for promoting an uncritical acceptance of authority (Perry, 2004). In addition, religious schools often emphasise conveying facts and information that leads to the accumulation of knowledge through rote memorisation (Demirel Ucan & Wright, 2019). CT is seen as an inseparable part of the Islamic tradition (Ahmed, 2019; Berglund, 2017; Berglund & Gent, 2019). On the other hand, there are concerns that religious schools fail to meet the pedagogical needs of public schools (references are needed). Traditional approaches and the lack of need for CT development were identified as significant challenges in junior secondary schools.

Based on this, this study aimed to analyse the effect of TEQ, PS, and conventional strategy (CS) on students' CT and CK, considering the type of school they study. Thus, the research question (RQ) proposed in our work focuses on the following:

RQ 1: What is the difference in the CT and CK in students who are given TEQ, PS, and CS strategies?

RQ 2: What is the difference between CT and CK in students in public and private schools after being given TEQ, PS, and CS learning?

RQ 3: How is the relationship between CT and CK?

Method

Research design

This study used a quasi-experimental design with the pre-test-post-test non-equivalent control group (Creswell, 2014). We vary the teaching methods, which include Thinking Empowerment by Questioning (TEQ) (Amin et al., 2019; Hariyadi et al., 2018; Kristiani et al., 2015; Saputri & Corebima, 2020), problem-solving (PS) (Pólya, 1971), and conventional strategy (CS) (Suwono et al., 2021). CS is a teaching strategy commonly used in schools (Irnidayanti et al., 2020). To determine and compare the effect of TEQ with PS and CS on CT and CK, the experimental group participated in TEQ, the control-I group taught in PS, and the control-II group taught CS. Before and after teaching, the three groups took pre and post-test.

Working group

The study group consisted of 176 seventh-grade students who studied at General Junior High School (SMP) Negeri 7, SMP Negeri 3, MTs Negeri 427, and Islamic Junior High School (MTs) Darul Ulum in Ternate, Indonesia, which enrolled in Biology courses in 2021. Background information on the students who participated in the study, such as their previous study success in school, was compared, and no differences were found based on the ANOVA test (p-value > 0.05). The study's design was quasi-experimental because the sample lacked the proper randomisation of the groups, and the set included a non-equivalent control group (Cohen et al., 2011). Randomness was pursued by dividing the six groups into two experimental and four control groups in alphabetical order. Given the quasi-experimental design of the intervention, we decided to include eligible students: (1) present during teaching and (2) taking pre- or post-tests. Table 1 presents the distribution by school type and group (experimental and control). The course was administered in a similar phase of the semester in all schools.

Table 1. Distribution of participants (n= 176)

Group	Intervention	School	Amount (n)
Experiment	TEQ	Religious	29
		General	32
Control-I	PS	Religious	28
		General	32
Control-II	CS	Religious	26
		General	29

It is also important to emphasise that ethical authorisation for this research was obtained from the local education office, the school's principal where the research was conducted, and the participating teachers. The students, as participants, were informed about the purpose of the study, participated voluntarily, and the responses given were kept confidential (anonymity). The biology teachers involved in this study were the teachers who showed an interest in participating, gave written consent, and gave the researcher permission to access the class as observers.

Experimental process and Teaching environment

The educational intervention for biology takes one semester and was set out in three stages. *First*, the preparation stage consists of: (1) group formation; (2) explanations to participants about the research objectives, assessments, and rules during the delivery of the intervention; and (3) conducting a pre-test. *Second,* the development stage involves designing strategies and teaching units (including student sheets). The TEQ, PS, and CS strategies stages are presented in Tables 2, 3, and 4. The teaching units studied by students are considered based on the essential competencies in the applicable curriculum. There are four units of learning material studied, namely (1) biotic and abiotic natural phenomena, (2) the characteristics of living things, (3) the classification of living things, and (4) the organisation of life. It should be noted that: (1) all sessions are 90 minutes long, and (2) teachers who participated in teaching using CS in the previous semester and had gone through training on the learning strategies to be implemented. *Third,* a post-test was carried out after the strategy and teaching unit ends.

Table 2. Stages of TEQ learning

Phase	Learning Activities
1	The teacher distributes worksheets containing discourse about the "characteristics of living things" on some pages then students are asked to read them. Students make a summary of the readings a few days before learning begins.
2	The teacher guides students to do a practicum in large groups. Students are asked to identify environmental components such as humans, cats, plants, soil, and rocks and then describe what symptoms appear and are classified as biotic or abiotic.
3	The teacher assigns students to work on questions on reflection, for example, "Did you know that humans are included in the biotic component?" "Did you know that in nature, there are biotic and abiotic components and their benefits?" Think, for example, "Do the biotic and abiotic components found in nature have anything in common?" Evaluate, for example, "Explain the difference between abiotic and biotic components and the symptoms of abiotic and biotic nature?" part of the worksheet, which is done individually.
4	The teacher assigns students to work on the questions on the reflect, think, and evaluate part of the worksheet, which is carried out in groups.
5	The teacher assigns students to present their work on the worksheet.

(adapted from Amin et al., 2019; Hariyadi et al., 2018; Kristiani et al., 2015; Saputri & Corebima, 2020).

Table 3. Stages of PS learning

Phase	**Learning Activities**
Understanding the problem	The teacher divides students into groups and then asks students to read the questions correctly.
Create a problem-solving plan	The teacher assigns students to work on necessary problems on student worksheets, for example, "What is the difference between biotic and abiotic components?" Assign students to find the relationship between the information provided in the worksheet and the unknown. Assign students to analyse the results of the problem formulation and create hypotheses "The biotic factors refer to all the living beings, and the abiotic factors refer to all the non-living components like physical conditions (temperature, sunlight, etc.)". Work in groups.
Executing the plan	Students check each step in the plan and write it down in detail on the PS sheet to ensure that each step is correct.
Review the results of his reading	Students review the results obtained, for example, "In ecology, abiotic components (chemical and physical parts of the environment) that affect living organisms and the functioning of ecosystems." Students are assigned to present their results in front of the class, and other students criticise them.

(adapted from Pólya, 1971)

Table 4. Stages of CS learning

Phase	Learning Activities
1	The teacher explains the topics, concepts, principles, and knowledge of "characteristics of living things".
2	The teacher gives questions, followed by students who answer the questions on the worksheet, for example, "Explain the difference between abiotic and biotic components!"
3	Students present their work individually.
4	Teachers assess student achievement of instructional objectives.

(adapted from Suwono et al., 2021)

Data collection tools

The instruments used in this research are questions that refer to the essential competencies of biology science subjects, a critical thinking skills rubric, and a concept understanding rubric. All instruments have been content and empirically validated.

Pre and post-test questions

CT and CK skills were examined using essay questions conducted before (pre-test) and after intervention (post-test). The questions in the test were adjusted to the curriculum objectives (Table 5). The test is in the form of an essay with ten questions where at least each question requires students to respond critically using their scientific knowledge. Measurement of critical thinking and content knowledge has each purpose. For example, students are asked the question, "compare plants and animals", and then the measurement of content knowledge is seen in how students explain the concepts and characteristics of plants and animals. While critical thinking is seen in how students identify differentiating aspects, analyse where the differences are, and then make inferences.

The test contains all the concepts of the four teaching units during the intervention. The researcher prepared the test questions with the science teacher in each school referring to the textbook. These questions were tested on students before use, and their validity and reliability were measured for CK and CT. Measurement of validity with Pearson correlation shows that all questions have a p-value of less than 0.05, which means all questions are valid. Measurement with Cronbach's alpha above 0.70 means the instrument has good reliability (Taber, 2018).

To ensure the reliability of the results, we engaged two primary investigators to carry out the assessment. *First*, we conducted an independent assessment using a pre-compiled rubric. *Second*, we discuss the results of unequal assessments to reach an agreement. We ensure that the inter-reliability is above 0.90.

Critical Thinking Skills (CT) Rubric

The measurement of critical thinking skills is integrated with the essay test questions. The critical thinking skills rubric used to measure critical thinking refers to Finken and Ennis (1993) on a scale of 0-5. More details see Zubaidah et al. (2020). The rubric criteria are as follows:

- The answer has a theoretical basis with clear concepts
- The answer is accompanied by a strong, correct, and clear reason
- The answer has a good line of thinking, includes all concepts that are interrelated and integrated
- The grammar is good and correct
- All aspects are visible, and the evidence is good and balanced
- Doing deduction and induction
- Carry out evaluation

Conceptual understanding rubric (CK)

Measurement of integrated concept understanding in essay test questions. The rubric used to measure concept understanding refers to Hart (1994) on a scale of 0-4. The rubric criteria are as follows:

- Answers have a theoretical basis accompanied by clear and correct concepts.
- The answer is accompanied by a strong, correct, and clear reason.

Based on these criteria, 0 points are given if there is no answer, point 1 if the answer is not correct, point 2 if the answer is correct but not sequentially, point 3 if the answer is correct and sequential but not accompanied by an explanation, and point 4 if the answer is correct, sequentially and accompanied by an explanation.

Table 5. Learning outcomes in the 7th-grade biology curriculum and related questions

Chapter	Learning outcomes	Related question	Sample items
Symptoms of biotic and abiotic nature	Carry out planned and systematic observations of objects to obtain information on natural biotic and abiotic phenomena	1a, 1b, 1c	Explain the difference between biotic and abiotic natural phenomena.
Characteristics of living things	Identify the characteristics of living things	2a, 2b, 3a, 3b, 4	Explain the difference between animals and plants!
Classification of living things	Classify living things based on their characteristics	5a, 5b, 5c, 6, 7, 8a, 8b, 8c	Cats, dogs, and tigers have something in common, including the structure of their teeth and the type of food they eat. Therefore, the three animals are grouped in one taxon..name, and explain the statement!
Organisation of life	Describe the diversity in living organisational systems from the cellular to the organism.	9a, 9b, 9c, 10a, 10b, 10c	What is the relationship between cells and organisms that you know?

Data analysis

Data analysis in this study used descriptive and inferential statistics. Descriptive statistics can help in summarising data in the form of simple quantitative measures such as histograms. Meanwhile, inferential statistical tests are used to compare the mean scores and express them in terms of statistical significance (Kaliyadan & Kulkarni, 2019). We convert raw scores to values in 0–100 to simplify the analysis process. Conversion is carried out based on suggestions from the rubric provided to get the average score of the measurement domain. In addition, in the academic guidelines, we use a scale. *First*, we calculated the mean and standard deviation for the CT and CK variables. *Second*, we checked that the CT and CK test data (measurements before and after intervention) had a normal and homogeneous distribution, in which we applied the one-sample Kolmogorov-Smirnov test (Table 6) and Levene's test for equality of variances (Table 7).

The analysis results show that the variables meet the assumptions of normality and homogeneity. Therefore, applying the ANCOVA parametric test and Pearson correlation was decided.

- The two-way ANCOVA test was used to answer RQ 1 and 2 to investigate differences in CT and CK scores between groups (TEQ, PS, and CS) in the two types of schools. If the results are significantly different, then further tested with the Least Significant Difference (LSD).
- Pearson correlation calculation to answer RQ 3 investigates the possible correlation between CT and CK in the TEQ treatment.

Table 6. Normality test using one-sample Kolmogorov-Smirnov test

		Pre-test CT	Post-test CT
N		176	176
Normal Parameters	Mean	29.53	66.73
	Std. Deviation	4.078	7.086
Most Extreme Differences	Absolute	0.074	0.062
	Positive	0.074	0.054
	Negative	-0.057	-0.062
Kolmogorov-Smirnov Z		0.982	0.822
Asymp. Sig. (2-tailed)		0.290	0.509
a. Test distribution is Normal.			
		Pretest CK	Post-test CK
N		176	176
Normal Parameters	Mean	30.44	67.76
	Std. Deviation	3.971	7.071
Most Extreme Differences	Absolute	0.069	0.073
	Positive	0.069	0.039
	Negative	-0.047	-0.073
Kolmogorov-Smirnov Z		0.919	0.974
Asymp. Sig. (2-tailed)		0.368	0.299
a. Test distribution is Normal.			

Table 7. Homogeneity test using Levene's test for equality of variances

F	df1	df2	Sig.
0.775	2	173	0.462
Tests the null hypothesis that the error variance of the dependent variable is equal across groups.			
a. Design: Intercept + Pre CK + Group + School + Group*School			
F	df1	df2	Sig.
1.048	5	170	0.391
Tests the null hypothesis that the error variance of the dependent variable is equal across groups.			
a. Design: Intercept + Pre CT + Group + School + Group*School			

Results

Conceptual knowledge

This study aimed to determine whether there was a significant difference between the levels of CK in students treated with TEQ, PS, and CS, taking into account the type of school. This difference was tested using the two-way ANCOVA analysis method and was interpreted at a significance level of 0.05 (Table 6). The mean pre-test score of CK in control group I (M= 31.07; SD= 3.95) and control group II (M=30.38; SD= 4.10) increased after the pre-test, with post-test scores (M= 68.63, SD= 5.02 for the control group I). and M=62.10, SD= 5.84 for control II). Meanwhile, the average score of the experimental group with the TEQ intervention before the test (M=31.84; SD=3.71) increased to post-test (M=73.19; SD=5.46). In this case, both the experimental and control groups experienced increased CT skills. Still, the increase in the experimental group was more significant than the two control groups

(Figure 1). The results of the analysis of the CK variable by ANCOVA and LSD tests are presented in Tables 8 and 9.

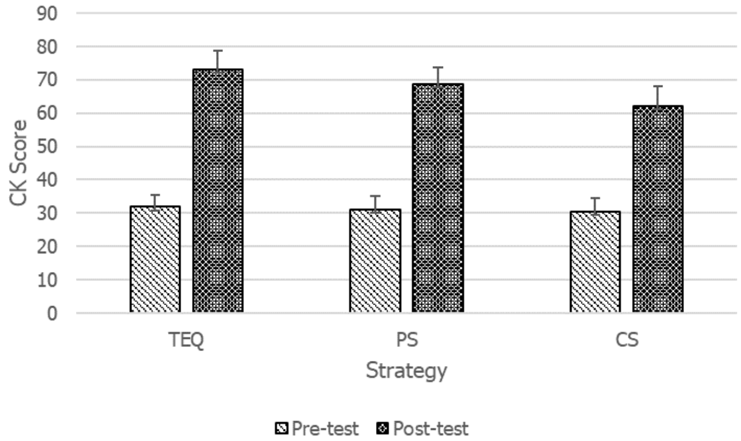

Figure 1. Pre-test and post-test CK on three learning strategies

Table 8. ANCOVA test results on the CK variable

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Model	4399.310[a]	6	733.218	28.852	0.000	0.506
Pretest CK	147.653	1	147.653	5.810	0.017	0.033
Group	3280.044	2	1640.022	64.534	0.000	0.433
School	449.554	1	449.554	17.690	0.000	0.095
Group * School	49.953	2	24.976	.983	0.376	0.011
Error	4294.855	169	25.413			
Total	826510.570	176				

Table 9. LSD test on the CK variable in the three learning strategies

Comparison		Mean difference	Standard error	Sig. [b)]	The 95% confidence interval for difference [b)]	
Group	Group				Lower bound	Upper bound
TEQ	PS	4.421*	0.921	0.000	2.602	6.240
	CS	10.763*	0.950	0.000	8.887	12.638
PS	TEQ	-4.421*	0.921	0.000	-6.240	-2.602
	CS	6.342*	0.945	0.000	4.476	8.208
CS	TEQ	-10.763*	0.950	0.000	-12.638	-8.887
	PS	-6.342*	0.945	0.000	-8.208	-4.476

Based on estimated marginal means:
[*)]The mean difference is significant at the 0,05 levels.
[b)]Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

The calculations using ANCOVA showed a significant difference in the levels of CK in the three groups (F= 64.534; p-value= 0.000) with a small effect size ($\eta^2 = 0.433$). Further testing with LSD showed that the TEQ group differed from the two control groups (PS and CS), and the PS control group differed from the CS group (Table 9). The analysis results of the type of school show differences between public and private schools (F= 17.690; p-value= 0.000), but the effect is classified as trivial ($\eta^2 = 0.095$). Based on the variables of school type (interaction of learning strategy treatment and school type), it can be said that there is no significant difference between the two types of schools in the three treatments (F= 0.983; p value= 0.376). These findings indicate that learning activities with TEQ are more effective for developing students' CK compared to PS and CS and have a similar effect on the two types of secondary schools.

Critical thinking

The two-way ANCOVA technique was used to analyse the impact of the TEQ strategy on students' CT skills in two types of junior high school Biology science subjects. The mean value of the control group I (M= 29.91; SD= 4.20) and control group II (M= 28.99; SD= 4.27) in the pre-test was almost the same as the experimental group (M=31.05; SD= 3.50), but the mean value the achievement of the experimental group (M= 72.50, SD= 5.54) in biology science subjects was higher than the control group I (M= 67.84; SD= 5.04) and control group II (M= 60.60; SD= 5.02) (Figure 2). The results of the analysis of the CT variable by ANCOVA and LSD tests are presented in Tables 10 and 11.

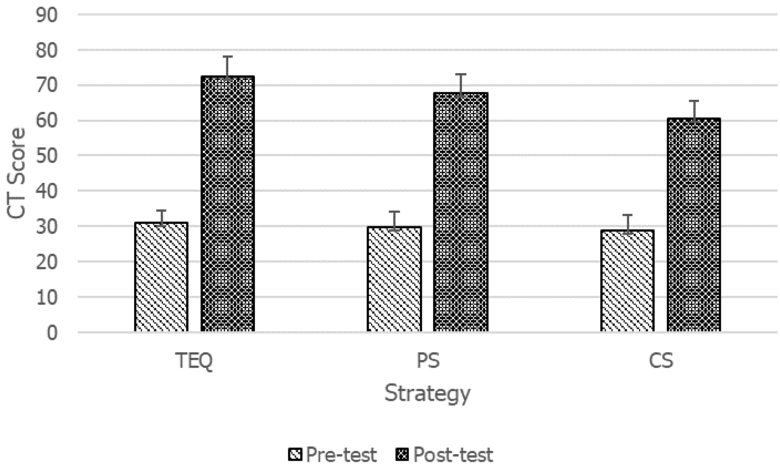

Figure 2. Pre-test and post-test CT on three learning strategies

Table 10. ANCOVA test results on the CT variable

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Model	5208.657[a]	6	868.110	40.487	0.000	0.590
Pretest CT	554.701	1	554.701	25.870	0.000	0.133
Group	3403.436	2	1701.718	79.366	0.000	0.484
School	216.410	1	216.410	10.093	0.002	0.056
Group * School	89.453	2	44.727	2.086	0.127	0.024
Error	3623.611	169	21.441			
Total	803426.584	176				

Table 11. LSD test on CT variables in the three learning strategies

Comparison		Mean difference	Standard error	Sig. b)	The 95% confidence interval for difference b)	
Group	Group				Lower bound	Upper bound
TEQ	PS	4.176*	0.850	0.000	2.449	5.853
	CS	11.032*	0.882	0.000	9.291	12.772
PS	TEQ	-4.176*	0.850	0.000	-5.853	-2.449
	CS	6.856*	0.870	0.000	5.138	8.573
CS	TEQ	-11.032*	0.882	0.000	-12.772	-9.291
	PS	-6.856*	0.870	0.000	-8.573	-5.138

Based on estimated marginal means:

*)The mean difference is significant at the 0,05 levels.

b)Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

The results of this two-way ANCOVA analysis to determine whether the experimental group was influential or not are presented in Table 8. According to the ANCOVA results, significant differences were identified between CT levels in the three groups (f= 79,366; p value= 0.000) with a small effect size (ɲ2 = 0.484). According to the results of the LSD test (Table 11) between the corrected post-test scores, the CT level of the experimental group (M= 72.13) was higher and significantly different than the control group I (M= 67.95) and control group II (M= 61.095). The analysis results of the type of school show differences between public and private schools (F=10.093; p-value= 0.000), but the effect is classified as trivial ($ɲ^2$ = .056). Based on the variables of school type (interaction of learning strategy treatment and school type), it can be said that there is no difference in CT levels between the two types of schools in the three treatments (F= 2.086; p value= 0.127). In this context, it can be said that the TEQ strategy effectively increases students' CT in public and religious schools.

Relationship between conceptual knowledge and critical thinking

Considering the effect of effective TEQ in Biology science subjects concerning students' CK and CT after the intervention, the Pearson correlation test was applied to identify the relationship between the two variables. The results showed a significant correlation between CK and CT (r= 0.948; p-value= 0.000) (Table 12). Therefore, the following relationship can be established: the more significant the students' CK in science, the better their CT skills, and vice versa (Figure 3).

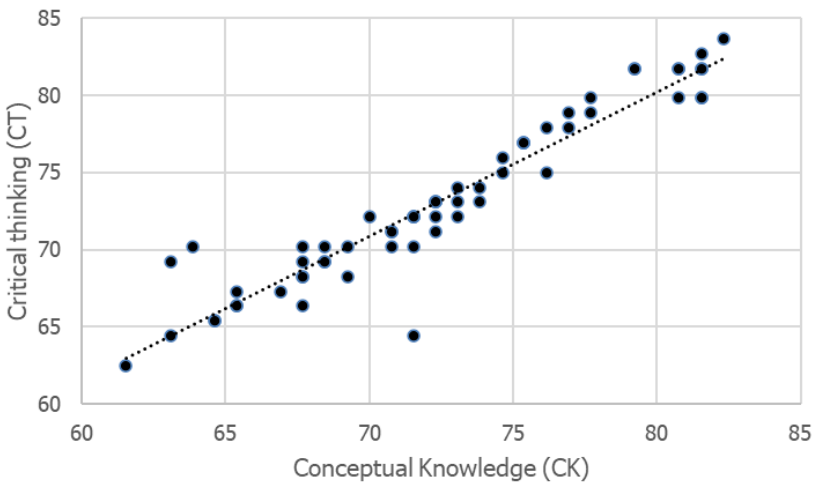

Figure 3. Correlation between CT and CK on the TEQ strategy

Table 12. Correlation test results between CT and CK on the TEQ strategy

		Pos_TEQ_CT	Pos_TEQ_CK
Pos_TEQ_CT	Pearson Correlation	1	0.948**
	Sig. (2-tailed)		0.000
	N	61	61
Pos_TEQ_CK	Pearson Correlation	0.948**	1
	Sig. (2-tailed)	0.000	
	N	61	61

**. Correlation is significant at the 0.01 level (2-tailed).

Discussion

This study's main objective was to test TEQ's effectiveness on CK and CT students in Biology. This proof is essential, considering many teachers spend more time asking questions

(Levin & Long, 1981). Currently, teachers are also directed to ask questions at the beginning of learning to increase students' motivation and involvement in learning and considered to increase CT (Paul & Elder, 2013; Tofade et al., 2013). Although the discussion about active learning to improve students' CT in science content is increasing, only some studies have emphasised the importance of question formulation activities (Chin & Osborne, 2008). A meta-analysis by Hattie et al. (1996) found that only 100 out of 40,000 studies discuss asking as an effective learning method. Thus, the primary purpose of this study is to strengthen references and empirical evidence about the effectiveness of learning by asking questions.

In the context of this research, it is hoped that junior high school students will have the experience to improve their CK and CT skills through activities to formulate questions, have in-depth discussions, and make decisions. Cuccio-Schirripa and Steiner (2000) explain that questioning is a thought-processing skill embedded in critical thinking and problem-solving. Regardless of the students' asking capacity, they can pay attention actively in the learning process when asking and responding to questions (Wale & Bishaw, 2020). This study believes that TEQ learning has better effectiveness for building students' CK and CT than conventional learning. Active learning only sometimes has a better effect than conventional teaching, but it offers promising student benefits (Engel & Randall, 2009; Van Klaveren, 2011).

Concerning question 1, the comparison of the effect of TEQ as an experimental group with the other two control groups on students' CK and CT was analysed using the ANCOVA technique. The data obtained from the pre-test and post-test CK tests revealed a significant difference in CK levels between the experimental and control groups. In this context, it can be stated that active learning activities are effective at the success rate of students' CK. Crogman and Trebeau Crogman (2016) argues that the questioning method is the basis for the Constructivist method. Questions are essential in understanding students' thinking in constructing knowledge (Salmon & Barrera, 2021). In short, knowledge can come from questions (Serrat, 2017). Thus, the TEQ method is more effective in teaching science content.

TEQ's effect on students' CT was also significant (Cohen et al., 2018). These results can be used to respond to the fact that the TEQ teaching method tends to give better results regarding promoting student CT. Specifically stated that TEQ can allow students to engage in an in-depth discussion process and they are involved in creating new ideas and better solutions (Rothstein et al., 2011) and make Biology more exciting and relevant to their lives (Chin & Brown, 2002). In this sense, the promotion of students' CT in learning activities depends on several things: (1) formulating important questions; (2) collecting relevant information; (3) being open-minded to find various alternative solutions; (4) discussing effectively; (5) take the right decisions and solutions; and (6) doing reflection (Gokhale, 2012; Paul & Elder, 2013). For the RQ 1 review, we can assert that the TEQ teaching approach is ideal for developing students' CK and CT, even compared to the PS strategy.

For research question 2, judging from the average score, students in religious schools show better progress than public students after being given treatment. However, the ANCOVA analysis showed no significant difference between students in public and religious schools after the CK and CT analysis in TEQ, PS, and CS groups. In other said, this means that each treatment given has the same effectiveness. These results show that factors such as the emphasis on memorisation and the dismissive attitude of religious schools do not underlie students' lack of critical thinking. Even if they wish to adopt active learning, they can simultaneously have the knowledge and skills to stimulate discussion and answer critical questions as students in public schools. This finding is important because the Islamic education community is increasingly aware of the importance of critical thinking and pedagogy that involves in-depth discussion (Ahmed, 2019; Waghid, 2014).

Finally, for research question 3, the results show a strong correlation between CK and CT through the TEQ application. Similar findings emerged in previous studies (Hu et al., 2019; Joseph & Thomas, 2020; Suwono et al., 2021; Wulandari, 2018). This evidence shows that active learning will enable students to utilise their existing knowledge to solve specific problems readily. In other words, students need sufficient knowledge to ask questions (Miyake & Norman, 1979). Thus, students involved in active learning activities must have prior knowledge as a prerequisite for studying new content (Crogman & Trebeau Crogman, 2018).

CT and CK have a close relationship. CT can be said as the application of CK to solve problems by considering various points of view (Thonney & Montgomery, 2019). Building CK can create a good habit of promoting CT skills (Jiang et al., 2022). In another sense, the use of CK in daily life ensures that we advance the capabilities of CT (Demircioglu et al., 2022). CT is urgently needed for CK acquisition and construction (Halpern, 2014). Some teachers see that learning that contributes to the acquisition of CK, on the other hand, can also develop CT skills (van der Zanden et al., 2020).

Conclusion, Limitation And Future Work

This study supports the application of TEQ to improve the CK and CT of junior high school students, taking into account the type of school. The findings of this study allow us to conclude that:

- The TEQ strategy best promotes students' CK and CT in junior high school Biology subjects.
- The type of school does not affect the outcome of the intervention; in other words, the application of TEQ has the same effectiveness for students in public and religious schools.
- CK strongly correlates with CT and vice versa through the TEQ application.
- From the successful implementation of the TEQ intervention as an alternative strategy, we can extract several educational implications for teaching Biology to junior high school students:
- Active learning can increase student participation, give students more space to formulate questions and use it as an entry point for deeper discussions.
- Explanation of content that supports students in solving the questions asked encourages students to be more critical in learning content.
- In active learning, students can develop CK and CT through activities to formulate questions, gather information, discuss, and make decisions.

Although the main objective of this research is to provide a reasonably broad insight, the limitations of this study need to be considered. *First*, instead of the proposed methodology seeking to reduce the lack of randomisation by matching students based on initial ability. Causal inference is limited because participants are not randomly assigned to a particular treatment group or do not allow students to choose an experimental or control group voluntarily. *Second*, the sample size in each treatment group was small and was not applied to conclude the results in other cases, primarily since we focused on junior high school students. *Third*, the analysis results and these findings indicate that the student's final abilities still need to achieve maximum results; thus, they need to be interpreted with caution. Because critical thinking skills take a long time, a longer intervention time can provide more optimal results. *Fourth*, the positive comparison group only involved students with PS activities. *Finally*, further research must examine relevant issues with more complete parameters, including randomisation, diverse control groups, larger samples, and longer times. Research on these factors to improve conceptual understanding and critical thinking needs to be a concern.

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