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The Effectiveness of Write-to-Learn Social-Oriented-Scientific-Issues on Students' Critical Thinking and Argumentation Skills

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abstract

This research aimed to analyze the effectiveness of Write-to-Learn-Social-Oriented-Scientific-Issues' on the critical thinking and argumentation skills of grade eleven students. The study employed a quantitative approach and a quasi-experimental method and involved static groups of pretest-posttest design with two experimental classes. The strategies of the Write-to-Learn-Social-Oriented Scientific Issues were divided into two: Free and Guided Write-to-Learn. These strategies were implemented in each class. The Hotelling's Trace test showed that the strategy was less effectively implemented on students' critical thinking skills than on students' argumentation skills. Furthermore, the hypothesis test using the independent sample t-test showed that the Free Write-to-Learn-Social-Oriented-Scientific-Issue strategy effectively built students' critical thinking skills and argumentative abilities to learn biology. Meanwhile, the Guided strategy was less effectively implemented on critical thinking skills but was effectively applied to students' argumentation skills to understand biology.

1. Introduction

The 2013 curriculum is an integrated curriculum known as a system or learning approach that involves several disciplines and provides meaningful and broad experiences for students. The curriculum aims to give teachers more space to equally develop students' potentials in three aspects: cognitive, psychomotor, and affective aspects. Moreover, the curriculum must be supervised by synergistic rules; thus, students can finally learn enthusiastically and excitedly and achieve moral values in each material (Sofyan, 2019). The implementation of the 2013 curriculum is closely related to high-order thinking skills (HOTS). The HOTS refers to students' thinking process at a higher cognitive level developed from various cognitive concepts, cognitive methods, and learning taxonomies, such as problem-solving methods, bloom taxonomy, learning, teaching taxonomies, and assessment taxonomies (Sofyan, 2019).

Critical thinking is a part of HOTS and comprises activities that test, question, relate, and evaluate all aspects of a situation or problem. The critical thinking activity shows an ability to draw correct conclusions and see any contradictions, consistency, or irregularities in the information (Pusparatri, 2012). This study employed a strategy called the Write-to-Learn (WTL). Alkis (2018) proposes that the WTL strategy includes activities such as keeping a journal, writing

letters, and completing story activities. Moreover, it positively impacts students' conceptual understanding.

This study combined the WTL strategy with socio-scientific issues. Active interaction of all students was expected from this combination. Therefore, dynamic interaction becomes an interesting discussion. This statement is supported by Robert (2010), who states that issue-based discussion is a participatory, collaborative, and cooperative learning method. The method discusses a problem or issue to present and find solutions. The discussion prioritizes brainstorming to construct collaborative knowledge.

Socio-scientific issues in this study were related to the nervous system material. Balgopal et al. (2016) argue that there is a need to make guidance to consider the students' willingness to make local environmental SSIs and potential solutions to resolve these issues along with the discussions of the most meaningful evidence to support their particular claims. Teachers can help students become more thoughtful of their arguments and frames to use.

The relationship between argumentation and critical thinking is emphasized by Keraf (2004), who argues that the bases of argumentative writing are critical and logical thinking. Without this ability, the students' writing only contains a non-useful stretch of sentences or paragraphs. An argumentation paper must contain rational and scientific data (Syaifudin & Utami, 2011).

To realize students' higher-order thinking skills as similar curriculum development, the activity that strengthens the ability should be familiarized. Critical thinking and argumentation skills are the main thinking skills learned in this study. Each of two thinking skills will determine two different write-to-learn (WTL) strategies: free and guided write-to-learn.

This study primarily aimed to analyze the application of the writing-to-learn-social-oriented-scientific-issue (SSI) strategy to improve students' critical thinking skills and students' argumentation skills. Furthermore, the purposes of this study were 1) to analyze the effectiveness of the Write-to-Learn-Social-Oriented-Scientific-Issue strategy on students' critical thinking and 2) to analyze the effectiveness of the Write-to-Learn-Social-Oriented-Scientific-Issue strategy on students' argumentation skills. In addition, the effectiveness of each strategy to each thinking skill was also investigated.

2. Method

This research employed a quantitative approach and a quasi-experimental method, using a static group pretest-posttest design adopted from Sukmadinata (2015). The Write-to-Learn (WTL) is a new strategy, thus, an introductory study because there were no rules about what types of texts belong to the WTL strategy. The population of this study was class XI MIPA (Science) in SMA Negeri 8 Cirebon. Meanwhile, the samples of this study were 27 students of class XI MIPA 1 and 29 students of XI MIPA 3. Class MIPA 1 was used as the experimental class 1, and class MIPA 3 was used as the experimental class 2. The biology material brought in this research was the nerve system.

The research design delivered two main instruments. The first instrument was the pretest-posttest question, consisting of 35 validated questions based on five critical thinking indicators by Alec Fisher. Those indicators are 1) identifying elements of a case, especially reasons and conclusion, 2) identifying and evaluating assumptions, 3) assessing acceptability, especially credibility and claim, 4) analyzing, evaluating, and generating explanation; and 5) analyzing, evaluating, and deciding (Fisher, 2009).

The second instrument was the students' worksheet, consisting of the realization of the WTL strategy. This research employed the analytic memo, an argumentative essay, derived from Angelo and Kathryn's book (1993). The book entitles Classroom Assessment Technique: A Handbook for College Teachers (2nd edition). It consists of some components adopted from

various researchers: Cope et al. (2013) "Science in Writing: Learning Scientific Argument in Principle and Practice"; Nam and Chen (2017) "Promoting Argumentative Practice in Socio-Scientific Issues through a Science Inquiry Activity"; and Walker et al. (2012) "Learning to Argue and Arguing to Learn: Argument-Driven Inquiry as a Way to Help Undergraduate Chemistry Students Learn How to Construct Arguments and Engage in Argumentation During Laboratory Course."

The analytic memo, combined from four researchers, consisted of four elements: claim, evidence, reasoning, and conclusion. These elements aimed to facilitate the students because they were still in Senior High School and rarely got this task. The score of this worksheet was used as an argumentative skills score. The first experimental class implemented the free WTL strategy, referring to writing an argumentative text without additional words. Meanwhile, the second experimental class implemented the guided WTL strategy, referring to writing an argumentative text with different words.

The data were analyzed in two steps. The first was analyzing the assumption test that consisted of three tests normality test, homogeneity test, and Hotelling's trace (T2) Test. The normality and homogeneity test tested critical thinking and argumentation skills' pretest score with significance level $\alpha = 0.05$. This test consisted of multivariate testing using the Mahalanobis distance with the qi (chi-square) value (for the normality test); meanwhile, Box's M test was for the multivariate homogeneity test (Rencher, 2002). All tests were conducted using the SPSS application (16.0 version).

The two tests had a similar conclusion that if the significance score for each test had been more than its significance level ($\alpha = 0.05$), the data could have been considered normally or homogeneously distributed. The next step was conducting the Hotteling's Trace (T2) test for the pretest score. Hotelling's Trace (T2) test aims to examine if the data has a similar average or not and consists of multivariate testing with a significance level $\alpha = 0.05$ (Rencher, 2002). The Hotelling's Trace (T2) test concludes that if the p-value (Sig.) is < 0.05, H_1 or H_0 hypotheses are rejected. H_1 shows different average values of data while H_0 shows the opponent. The hypothesis of this research is as follows (Rencher, 2002).

$$H_0: \begin{pmatrix} \mu EP \\ \mu EA \end{pmatrix} = \begin{pmatrix} \mu KP \\ \mu KA \end{pmatrix}; H_1: \begin{pmatrix} \mu EP \\ \mu EA \end{pmatrix} \neq \begin{pmatrix} \mu KP \\ \mu KA \end{pmatrix}$$

Where:

μEP: Pretest or posttest scores of critical thinking items of experimental class 1

μEA: Pretest or posttest scores of argumentation skill worksheet of experimental class 1

μKP: Pretest or posttest scores of critical thinking item of experimental class 2

μKA: Pretest or posttest scores of argumentation skill worksheet of experimental class 2

The second step after analyzing the assumption test was testing the hypothesis. This test was defined for the posttest score. The hypothesis test consisted of three steps with the analysis assumption test and two types of the hypothesis test: independent sample T-test and one sample T-test. In conclusion, the steps in the hypothesis test were normality test, homogeneity test, Hotteling's trace (T2) test, independent sample T-test, and one sample T-test.

The hypothesis testing consisted of three steps similar to those in the analysis assumption test. The hypothesis testing aimed to discover any differences caused by treatment. Besides, the independent sample of the t-test aimed to test the relation between the pretest and posttest scores of each variable. The hypothesis test for an independent sample of t-test had a significance level of 0.05, using the following hypothesis.

$$H_0: \begin{pmatrix} \mu EP \\ \mu EA \end{pmatrix} \leq \begin{pmatrix} \mu KP \\ \mu KA \end{pmatrix}; H_1: \begin{pmatrix} \mu EP \\ \mu EA \end{pmatrix} \geq \begin{pmatrix} \mu KP \\ \mu KA \end{pmatrix}$$

Where: μEP: Posttest scores of critical thinking items of experimental class 1
μEA: Posttest scores of argumentation skill worksheets of experimental class 1
μKP: Posttest scores of critical thinking items of experimental class 2
μKA: Posttest score of argumentation skill worksheet of experimental class 2

One sample of the t-test was conducted to examine the effectiveness of each treatment in each class based on the posttest score. The hypothesis test for one sample of t-test had a significance level of 0.05, as presented in the following hypothesis.

$$H_0 = \mu \leq 60; H_1 = \mu > 60$$

The number criteria were based on the value converted into five scales. The applied standard was 60, and this score was according to students' minimum average score in all tests. This value was characterized as good. The criterion to accept the hypothesis is that the H_0 is rejected if the significance value is less than 0.05. If the significance value is more than 0.05, H_0 is accepted.

3. Result and Discussion

Writing refers to an activity representing what the students learn during the lesson. It is expected that writing activities enable students could recall memories. Reynolds et al. (2012) explain that the Write-to-Learn (WTL) strategy is a pedagogical approach that consists of an essay-making activity. Therefore, the students can make connections between the knowledge during the lesson and the students' learning styles.

Klein et al. (2018) explain that selecting a genre to support educational purposes is a pivotal process. Several types of writing strategies are 1) journal writing, 2) summary or discourse synthesis, 3) argumentation, 4) the science writing heuristic, and 5) composing to learn with multimodal representation. The writing genre in this research was argumentative writing that combined socio-scientific issues. The argumentative texts on the student worksheets were different for each class. Figure 1 shows students' worksheets for both classes used for experiment class 1 (left) and experimental class 2 (right). This worksheet was used to write a complete argumentative text with all components. According to Galma and Agus (2016), repetition in writing is necessary because it enhances students' thinking ability and learning outcomes.

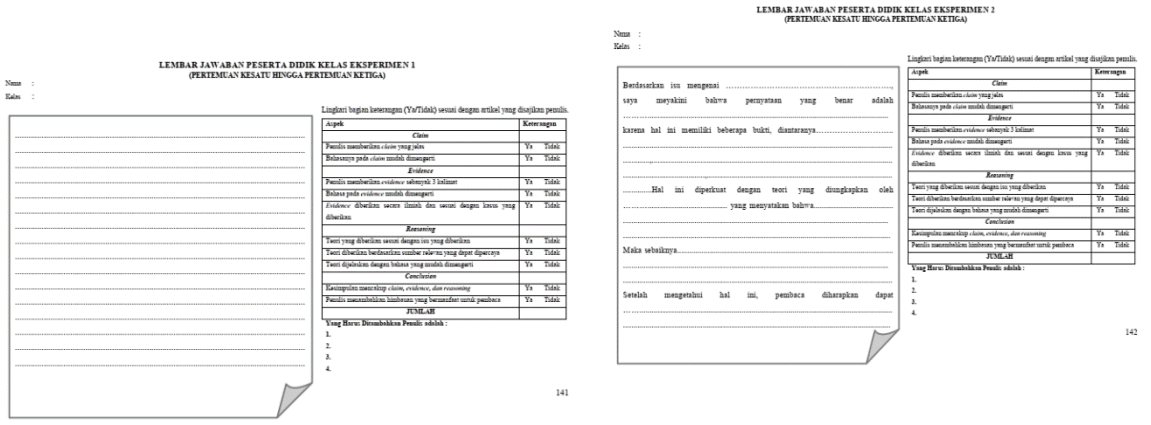

Figure 1. Free WTL's worksheet (left) and guided WTL worksheet (right)

The argumentative text was based on socio-scientific issues discussed during the lesson. There were four or five socio-scientific issues discussed, and they depended on the material. During the lesson, the students were in the classroom and were divided into several groups, considering the amount of SSI.

The examples of the SSI discussed during the lesson are as follows; 1) Does the consumption of Monosodium Glutamate (MSG) make you stupid?; 2)Does falling in a sit position while you

want to sit make you blind?; 3) If someone hits your head with a wood stick, will you automatically get amnesia?; 4) If someone is not good at Mathematics, does it mean that he is not smart?; 5) How to reduce the addictive effect of smoking?; and 6) Can consuming candy can reduce this effect?. These SSI examples were chosen based on several references. Fensham (2012) categorizes the SSI scheme using the Cynefin Framework based on scientific certainty and human risk levels. Another concern was selecting socio-scientific issues for teaching. The categories of fixing socio-scientific issues of this framework were the simple, complicated, complex, and chaotic cases. There is some guidance to select socio-scientific issues (Zeidler & Kahn, 2014), as follows: 1) Considering controversial issues with social and scientific connections; 2) Deliberating moral and ethical dilemmas involved; 3) Having opportunities for argumentation and discourse, and 3) Having contexts for rigorous science content and process skills.

Hancock et al. (2019) served several questions of when teachers should implement socio-scientific issues in the class. These questions were intended to enhance the learning process and included several points, as follows. 1) What unanticipated problematic aspects associated with the selected SSI units emerge during the classroom implementation? 2) How do teachers perceive their students' responses to the selected issue? As teachers implement their initial SSI units, how do they identify the characteristics of a good SSI? 3) How does their issue of selecting criteria change and become refined over time?

The combination of the WTL strategy and SSI was to enhance the students' activity in class; thus, the discussion was more interesting and collaborative. Roberts and Gott (2010) state that the discussion about socio-scientific issues is a collaborative, participative, and cooperative discussion. Sadler et al. (2017) state that there are three steps in the learning phases of a learning model when using SSI: 1) encountering the focal issue, 2) engaging with socio-scientific, reasoning, and practices, and 3) synthesizing key ideas and practices. Sadler et al. (2017) statement, the learning process was the same. The SSI was introduced after the teacher described the lesson material and made a connection with the SSI. Then, after introducing the SSI, students should engage with it due to a component in the argumentative text.

The score for the argumentative text used data for argumentative skills, while the data for critical thinking skills were from the pretest and posttest instruments. Overall, Table 1 shows descriptive statistic data for treatments, dependent variables, and pretest and posttest scores.

Table 1. Descriptive Statistic Data From Both Class

Instruments	Groups	Mean	Std. Deviation	N
Pretest Scores of Critical Thinking Items	Free WTL	63.82	7.019	28
	Guided WTL	65.17	7.672	29
	Total	64.51	7.324	57
Posttest Scores of Critical Thinking Item	Free WTL	82.71	7.999	28
	Guided WTL	80.00	6.617	29
	Total	81.33	7.390	57
Pretest Scores of Argumentation Skill Worksheet	Free WTL	68.04	24.400	28
	Guided WTL	83.45	17.116	29
	Total	75.88	22.225	57
Posttest Scores of Argumentation Skill Worksheet	Free WTL	68.54	23.774	28
	Guided WTL	86.55	20.981	29
	Total	77.70	23.983	57

The discussion scope started from each analysis assumption test for the pretest and posttest. The description of the test results in each dependent variable was described in a short description.

Meanwhile, the hypothesis tests, namely independent sample T-test and one sample T-test, described the significance score for each test and its conclusion in detail. The whole tests were run with the SPSS application (version 16.0).

The analysis assumption test showed that the data were normally distributed with a significance score of 0.979. The test also showed that the data were homogeneously distributed with a significance score of 0.263. After knowing that the data were normally and homogeneously distributed, the Hotelling's Trace (T2) test could be conducted. The significance value of the T2 test was 0.026; thus, the accepted hypothesis was H_1. This finding signified that the data had different average values.

Furthermore, the hypotheses were tested after knowing the posttest score. The test results showed that the posttest scores were normally distributed with a significance value of 0.545. Besides, the posttest scores were homogeneously distributed with a significance value of 0.439. After normally and homogeneously being distributed, the significance value for the T2 test was 0.004. In other words, the score of the T2 test was similar to the previous one. Thus, the H_1 hypothesis was accepted, and this result indicated any differences within the average value of the data.

The effectiveness of the Write-to-Learn-Social-Oriented-Scientific-Issues on students' critical thinking

To measure the effectiveness of the research independent variables on critical thinking, this research employed the initial and final data of critical thinking items. The results of the independent sample t-test are shown in Table 2.

Table 2. Interpretation of independent sample t-test in critical thinking

Data	Independent Sample T-Test	
	Sig.	**Description**
Pretest and Post-Test Data of Critical Thinking Item	0.168	H_0 is accepted

Table 2 shows the significance value obtained from the test using the SPSS application. The test showed a value of 0.168. This number means that the significance was more than 0.05, and the H_0 hypothesis was accepted. In other words, the application of the WTL strategy was less effective on critical thinking skills. The results of this research were different from those of other research. Alkis (2018) explains that WTL strategies are still a useful activity and applicable in science lessons at all educational levels of primary schools. Sinaga & Feranie (2017) state that analyzing arguments, claims, or evidence increases critical thinking skills in the implementation of the Write-toLearn-Strategies due to several reasons. Both experimental classes employed a different format for writing. It caused a different interpretation and way when they constructed knowledge. For example, when students from the first experiment class wanted to create an argumentative text about Monosodium Glutamate (MSG), they did not have any clear guide to make it. Meanwhile, the second experiment class had guidance. These different writing formats affected the different knowledge construction.

The effectiveness of the Write-to-Learn-Social-Oriented-Scientific-Issues on students' argumentation skills

To measure the effectiveness of the independent research variables on the students' argumentation skills, this study employed the initial and final data of student worksheets. The results of the independent sample of the t-test are shown in Table 3.

Table 3. Interpretation of independent sample t-test in critical thinking

Data	Independent Sample T-Test	
	Sig.	**Description**
Pretest and Post-Test Data of Student Worksheet	0.004	H_0 is rejected

Table 3 shows the significance value obtained in the test using the SPSS application. The test revealed a value of 0.004, which means less than 0.05. This finding showed that the H1 hypothesis was accepted, and the application of the WTL using the SSI strategy was more effective in the students' argumentation skills. Moreover, Dawson & Carson (2020) argue that discussing climate change and socio-scientific issues can improve the students' argumentation skills.

Tables 2 and 3 stated that the WTL using the SSI strategy was less effective for critical thinking than for argumentation skills. The second experiment class applied an additional word in their worksheet and gained more scores than the other experimental class. Gere et al. (2018) state that specific components of writing assignments, such as meaning-making, interactive processes, clear expectations, and metacognition, are highly correlated with the students' greatest learning gains. The greatest learning outcomes refer to argumentation scores, not critical thinking scores, because the argumentation score of the second experimental class was higher than that of the first experimental class.

Without considering the score of the argumentative text, the discussion in the first experimental class was wider. There were multiple arguments, but the whole argument was a form of freedom of thought and did not refer to the suitable theory because the first experimental class did not use auxiliary words when writing articles. However, this was one of the advantages of the first experimental class. The argumentation process after the presentation in the first experimental class occurred spontaneously random in different parties. However, they were still structured and ran on a single topic extending to all aspects of an issue.

Considering two strategies of the Write-to-Learn (WTL), the additional discussion points determined which method was less effectively implemented in critical thinking but more effectively in argumentation skills. Though critical thinking and argumentation showed different results, they had a relationship. Roviati and Widodo (2019) state that the main characteristic of critical thinking to make a decision is an argument developed by each person. Argumentation and inquiry are crucial skills that develop critical thinking skills in science learning.

Furthermore, Macagno et al. (2015) stated how an argument becomes a component of critical thinking. In short, insufficient knowledge of evidence limits the quality of students' arguments, especially when they use evidence to evaluate knowledge, claim, and justify the argument. However, sufficient knowledge of certain issues does not necessarily lead to a good quality argument. Another influential factor is the ability to reason, and in this case, was choosing a reasonable or rational argument. This was crucial because an argument was a component of critical thinking.

The Effectiveness of Each Strategy to Students' Critical Thinking and Argumentation Skills.

The Free and Guided Write-to-Learn (WTL) has impacted students' critical thinking and argumentation skills. To analyze the effect, the hypothesis test used was a one-sample t-test. The strategy, data, and results are summarized in Table 4.

Table 4. The Summary of one-sample t-test result for each subject.

Types of Skills	Data Employed	Strategies	Results	Description
Critical thinking skills	Posttest scores of critical thinking items	Free WTL	0.000	H_0 was rejected.
		Guided WTL	0.068	H_0 was accepted.
Argumentation skills	Posttest scores of student worksheets	Free WTL	0.000	H_0 was rejected.
		Guided WTL	0.000	H_0 was rejected.

Table 4 presents that the guided WTL strategy was less effectively implemented in students' critical thinking skills. Meanwhile, all types of WTL strategies were effectively applied to students' argumentation skills. These results agree with Marzano, stating that writing activities give a chance for students to think about an argument and use higher thinking skills to face a complex problem. Writing activities use as a tool to reconstruct the knowledge and increase higher thinking skills. Furthermore, writing activities have been used as a strategy to increase students' conceptual learning (Quitadamo & Kurtz, 2007).

The use of the SSI-based scientific writing system agrees with the learning activities recommended by the 2013 curriculum. Students actively participated in class discussions, especially discussing socio-scientific issues. This study proved that many students began to argue with one another to support and defend their claims during the learning activities. Discussions appeared a lot in the first experimental class because the article writing systems did not use additional words. Consequently, the students argued a lot to find the right conclusions from the discussed issues.

The students' activeness in both classes is in accordance with Britton, who states that the Write-to-Learn (WTL) strategy provides a significant tool to strengthen reading comprehension activities and allows students to ponder and inform questions and ideas. The WTL strategy helps students more actively learn (Meiers & Knight, 2007).

Sampson et al. (2013) opine that the WTL approach has several constraints associated with the implementation. First, and most importantly, there is little focus on the nature of scientific writing in general or science-specific development of argumentative writing skills in particular. Therefore, students had few opportunities to learn objectives, assumptions, procedures, and rules "hidden" in scientific writing or to adopt norms and standards used to assess the quality of scientific explanations and arguments.

Students' activities show an active discussion about socio-scientific issues through the WTL strategy. This phenomenon is supported by Herlanti (2016), stating that discussing sociocultural issues improves students' argumentative skills. Argumentation is interpreted as the process of making arguments to justify beliefs, attitudes, and values and to influence others. When discussing socio-scientific issues, participants will put forward many arguments and must make a strong argument; thus, other participants will accept it. Students' scientific argumentation skills can increase as a result of the application of socio-scientific issues learning strategies (Siska et al., 2020)

Strong arguments are formed if the reasons are logical, rational, and critical. The habituation process to incorporate theories relevant to certain issues must be encouraged in scientific writing; thus, the resulting arguments are strong. Various informal reasoning will significantly develop during the discussion of socio-specific issues, such as what happened before the presentation and discussion process. The argumentation ability in terms of critical explanations, creative thinking,

and problem-solving will increase if learning to discuss socio-scientific issues continuously develop.

The socio-scientific issue has the potential to provide students with an argumentative environment with two important dimensions: 1) Social negotiation; students can discuss, defend, and refute arguments to build consensus. 2) Epistemic understanding of arguments, students can develop an understanding of what counts as a valid and good argument and apply the understanding to build and criticize other people (Hand et al., 2016).

Scientific writing activities can be alternative learning in the curriculum. The learning process uses a socio-scientific issue as it is subject relating to socio-scientific decision-making. However, it essentially still operates as a curriculum that focuses on the mastery of biological content (Sofie & Jan 2016). This learning process makes students regard science from many sides and aspects because, in the 2013 learning, students are required to apply it. Moreover, they are required to participate more actively in classroom learning because the learning approach of the student center and argumentation activities can become an alternative classroom learning. Future research is expected to apply paperless assignments because many papers were used in this study.

4. Conclusion

This study concluded that applying the Write-to-Learn (WTL) oriented to socio-scientific issue (SSI) strategy was less effectively applied to students' critical thinking skills than students' argumentation skills. The result of the independent sample t-test on students' critical thinking skills was 0.168. This number was more than 0.05 and indicated that the WTL strategy was less effectively applied in critical thinking skills. However, the strategy was more effectively applied in students' argumentation skills. This is shown by the independent t-test score of 0.004 or less than 0.05. This score denotes that the WTL strategy was effectively implemented in students' argumentation skills.

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