26 (4), 2025, 2542-2556

Jurnal Pendidikan MIPA

e-ISSN: 2685-5488 | p-ISSN: 1411-2531

https://jpmipa.fkip.unila.ac.id/index.php/jpmipa

The Effect of Socratic Questioning-Based Student Worksheets on Improving Students' Critical Thinking Skills

Laila Hayati[1], Suyidno Suyidno[2,*], Sauqina Sauqina[1], Yasmine Khairunnisa[1], & Abd Rahman NF[3]

[1]Department of Science Education, Universitas Lambung Mangkurat, Indonesia

[2]Department of Physics Education, Universitas Lambung Mangkurat, Indonesia

[3]Department of Innovative Science and Mathematics Education, Universiti Teknologi Malaysia, Malaysia

Abstract: The Effect of Socratic Questioning-Based Student Worksheets on Improving Students' Critical Thinking Skills. Objective: The ability to think critically plays an essential role in students' achievement in the 21st century, yet its development in science classroom instruction continues to be insufficient. Science education can be monotonous, the content is often perceived as complex, and students typically lack confidence during discussions. This study investigates the influence of Socratic Questioning-based Student Worksheets (SQ-SW) on the improvement of critical thinking skills among junior high school students regarding excretory system content. The novelty of this study lies in the deliberate integration of Socratic questioning techniques into student workbooks, a topic that has been scarcely explored in previous research. **Methods:** This study employed a quasi-experimental framework with a Nonequivalent Control Group Design. Participants involved 64 eighth-grade students of SMP Negeri 27 Banjarmasin, Indonesia, selected through purposive sampling. The experimental group used the SQ-SW, while the control group used conventional worksheets. Data were collected through a validated response questionnaire and a critical thinking skills assessment, both of which have been confirmed as valid and reliable. Data were analyzed using a descriptive qualitative approach, normality and homogeneity tests, paired-sample t-tests, and independent-sample t-tests. **Findings:** The findings indicated that SQ-SW could be efficiently applied with a commendable rating. Students in the experimental group demonstrated notable progress in critical thinking, achieving a moderate N-gain (0.56), whereas the control group achieved only a minimal N-gain (0.11). Four critical thinking dimensions (question formulation, hypothesis creation, self-regulation, and conclusion formation) showed moderate advancement. However, the analytical dimension displayed more constrained growth. **Conclusion:** The use of SQ-SW significantly influences junior secondary students' mastery of excretory system content and their development of critical thinking. Integrating Socratic questions throughout student worksheets creates a systematic, motivating pedagogical approach that breaks conventional classroom routines while enhancing conceptual depth. This investigation introduces a fresh educational technique adaptable to diverse science subjects and academic stages.

Keywords: critical thinking skill, excretory system, science learning, socratic questioning.

▪ INTRODUCTION

In the era of Industry 4.0, critical thinking skills are vital for professional success, highlighting the myriad educational challenges faced by students and educators in the 21st century (Thornhill-Miller et al., 2023). Critical thinking skills are the basic skills that help students analyze and reason. These skills help them perform better in college by enabling them to solve problems, think creatively, and even generate new ideas (Bangun & Pragholapati, 2021). Therefore, the development of critical thinking skills is a main focus of the Independent Curriculum in schools. The curriculum highlights the need to comprehensively advance 21st-century competencies, including critical thinking (Rubini

Suyidno
*Email: suyidno_pfis@ulm.ac.id

DOI: http://dx.doi.org/10.23960/jpmipa.v26i4.pp2542-2556
Received: 14 September 2025
Accepted: 07 December 2025
Published: 12 December 2025

et al., 2019). Such skills function as a vital foundation for strengthening decision-making and problem-solving capacities, contributing to lifelong personal growth (Li et al., 2022). Consequently, the Indonesian curriculum emphasizes the cultivation and development of critical thinking skills. Educational frameworks globally share this priority as well (Alharbi et al., 2022). In the current, rapidly evolving educational environment, the ability to think critically and solve problems has become increasingly essential (Ragab et al., 2024). For this reason, schools need to teach students to think critically and encourage them to do so (O'Reilly et al., 2022).

In reality, students' critical thinking skills in Indonesia remain low. A significant portion of the global education system still relies heavily on traditional models: exam-focused, teacher-centered approaches (Ghaleb, 2024). Based on the 2022 Programme for International Student Assessment (PISA) results, Indonesia ranked 59th in reading literacy, 67th in mathematics literacy, and 65th in science literacy out of 81 countries assessed (Susanto et al., 2024). Such results highlight persistent difficulties learners encounter in analyzing data, evaluating evidence, and drawing scientific conclusions. These abilities are core critical thinking skills assessed by PISA. The global significance of the PISA framework is emphasized, positioning it as a vital tool for evaluating student proficiency on an international scale (Descartin et al., 2023). Similar shortcomings in critical thinking are observable within school science instruction. Students continue experiencing challenges when interpreting evidence, bridging abstract concepts with practical examples, and tackling issues using methodical approaches. Moreover, many learners passively receive material without questioning it or making real-world connections, largely due to conventional didactic teaching methods that focus on information transfer rather than fostering active involvement, thereby impeding the advancement of critical thinking (Kooloos et al., 2020). The delivery of science content and exam drill worsens this condition. As a result, the learning process becomes less meaningful and more difficult for students' deeper understanding. This issue is further supported by the researchers' initial study, which shows that students' critical thinking skills at one junior high school in Banjarmasin are low. Most students had difficulty analyzing questions and drawing conclusions. Besides that, they are less active in discussion due to a lack of self-confidence. Learning processes tend to be monotonous, rarely involve students' active participation, and leave them feeling bored. At the same time, the complex nature of the science material adds to the difficulty of understanding it. This incident shows how important it is to use a well-planned, engaging teaching approach to help pupils improve their critical thinking skills (Blyznyuk & Kachak, 2024).

This method allows students to integrate their ideas, analyze issues from various viewpoints, and assess possible solutions (Hu, 2023). Research has shown that Socratic questioning strengthens critical thinking, enriches students' understanding, and cultivates a culture of curiosity and contemplation, all of which are essential for addressing complex challenges and recognizing diverse perspectives (Favero et al., 2025). Socratic questioning has been shown to increase students' engagement and collaboration, thereby supporting the development of their critical thinking (Lintangsari et al., 2022). To make the implementation more systematic, Socratic questioning can be outlined in students' worksheets. Through student worksheets, learners develop stronger capabilities for examining scientific concepts and building knowledge, as well as for applying them through scientific discourse and problem-solving activities. (Ayunda et al., 2023). When

students can construct their own knowledge, learning is more meaningful and relevant to them (Suyidno et al., 2020). Critical thinking and the application of Socratic Questioning are analogous and interrelated in cultivating superior skills among students (Norillah et al., 2022).

Earlier studies have confirmed the effectiveness of Socratic questioning in promoting critical thinking (Arianti & Kusairi, 2020; Ho et al., 2023). However, none have investigated its integration with Student Worksheets (SW), leaving it unclear how this combination could guide students in generating questions, forming hypotheses, managing their cognitive processes, analyzing information, and reaching conclusions. Addressing this gap is especially important for topics like the excretory system in junior high schools, which are complex and conceptual, involving processes such as kidney filtration, liver metabolism, and lung gas exchange, as well as the interdependence among these organs (Ristanto et al., 2021). Such characteristics demand higher-order thinking, including analytical, evaluative, and self-regulatory skills, making SQ-SW an ideal scaffold for critical thinking in a structured and progressive manner. By providing targeted questions and guided activities, SQ-SW helps students connect organ structures with their excretory functions, reason through physiological processes, and draw meaningful conclusions rather than rely on rote memorization. Therefore, this study aims to address this gap by examining the effectiveness of SQ-SW in enhancing junior high school students' critical thinking skills, specifically on excretory system topics, in a context that has been relatively underexplored in the literature.

Therefore, this study aims to analyze the influence of SQ-SW on students' critical thinking skills regarding excretory system material. These skills are emphasized in the indicators of formulating questions, formulating hypotheses, self-regulation, analyzing, and concluding. In particular, this study aims to: (1) analyze the implementation of SQ-SW on excretory system materials; (2) determine the improvement of students' critical thinking skills before and after the implementation of SQ-SW; and (3) find out the difference in the critical thinking skills of students who use SQ-SW and conventional student worksheets. This research is expected to contribute to the development of more meaningful science learning techniques that enhance students' critical thinking skills at the junior high school level.

▪ METHOD

Participant

The participants in this study comprised all eighth-grade students at SMP Negeri 27 Banjarmasin. Using purposive sampling, two classes were chosen for the study: class VIII-B as the control group and class VIII-C as the experimental group, with 32 students in each class. The two classes were chosen because they have the same characteristics. Before the intervention, both groups control and experimental, were considered equivalent, as they demonstrated comparable academic achievement, prior science performance, and classroom participation. This equivalence was further confirmed by the critical thinking pre-test results, which showed no substantial differences between the two classes before treatment. Therefore, the disparity in critical thinking results post-treatment can be ascribed to the utilization of the SQ-SW, rather than to pre-existing inequalities between the groups.

Research Design and Procedures

This study employed a quasi-experimental design with a nonequivalent control group. This design involves two groups: an experimental class and a control class, without random assignment. Students in the experimental group were taught using SQ-SW, whereas those in the control group used the standard worksheets typically used in schools.

The study spanned five sessions and comprised three primary phases: preparation, implementation, and evaluation. During the preparation phase, multiple tasks were undertaken, such as creating instructional materials and assessment tools, having these tools validated by experts to verify their quality and appropriateness, establishing coordination with school administrators and subject teachers, and conducting a pilot test of the critical thinking instrument to ensure question clarity and correspondence with the designated indicators.

The implementation phase commenced with a pre-test for both the experimental and control groups to assess students' baseline critical thinking skills. Throughout the instructional sessions, the experimental class utilized the SQ-SW, whereas the control class employed traditional worksheets. Both types of worksheets contained the same practical activity titled "*Effect of Solute Concentration on the Filtration Process in the Excretory System.*" However, the main difference lay in the type and depth of the questions. In the conventional student worksheet. students were required to answer factual or memory-based questions, such as "What did you observe about the effect of the amount of salt on the remaining volume of water?" and "What is the relationship between the excretory system and the results of this experiment?" Socratic Questioning was not applied in the control group; thus, students were not trained to formulate deeper questions, generate hypotheses, engage in self-regulation, analyze critically, or draw comprehensive conclusions. The primary focus of the conventional worksheet was to strengthen conceptual understanding and factual mastery rather than systematically develop critical thinking skills.

After completing the learning sessions, a post-test was administered to both groups to evaluate changes in students' critical thinking abilities. During the evaluation phase, data from pre-tests, post-tests, and student response surveys were compiled and analyzed using appropriate statistical techniques to identify differences between the experimental and control groups. The study design is outlined as follows:

O_1	X	O_2
O_1		O_2

This study used a nonequivalent control group design with two groups: experimental and control. Initially, both groups underwent a pre-test (O1) to assess their baseline critical thinking abilities before any intervention. Subsequently, the experimental group received treatment (X) involving the SQ-SW, whereas the control group received instruction through a traditional worksheet. Following the completion of instructional activities, both groups completed a post-test (O2) to measure modifications in their critical thinking competencies. Thus, the experimental design is depicted as O1 X O2 for the treatment group and O1 - O2 for the comparison group. Here, O1 denotes the initial assessment, X represents the SQ-SW treatment, and O2 denotes the final assessment administered after teaching was complete.

Instruments

This study utilized two main instruments: a student response questionnaire and a critical thinking skills test. The student response questionnaire was designed to measure students' perceptions of the implementation of the SQ-SW in the learning process. The questionnaire consisted of 30 statements divided into six aspects, with each aspect measured by five items. These six aspects include: (1) engagement in learning, (2) understanding of the material, (3) improvement of critical thinking skills, (4) satisfaction with the learning method, (5) collaboration within groups, and (6) time management. Every item used a five-point Likert scale, offering choices ranging from strongly disagree to strongly agree. The questionnaire included statements of both positive and negative nature. Positive statements were scored from strongly disagree (1) through to strongly agree (5), whereas negative statements employed reversed scoring, with strongly disagree assigned (5) and strongly agree assigned (1). These six aspects were designed to reflect students' emotional, cognitive, and behavioral responses toward the implementation of SQ-SW in classroom learning activities.

Meanwhile, the critical thinking skills test was developed to assess students' ability across five indicators of critical thinking, which were adapted from the theories of Ennis (1993) and Facione (1990). The indicators, their theoretical sources, and operational meanings are presented below:

This study measured students' critical thinking skills through five indicators adapted from Ennis and Facione. The initial indicator, question formulation (Ennis – Identifying or Formulating Questions), pertains to students' capacity to recognize and develop essential questions from a presented problem or occurrence. The second indicator, hypothesis formulation (Ennis-Making Hypotheses), evaluates students' ability to generate logical assumptions or provisional responses that can be tested through systematic inquiry. The third indicator, self-regulation (Facione-Self-Regulation), indicates students' competence in organizing, overseeing, and assessing their cognitive processes during problem-solving. The fourth indicator, analysis (Facione-Analysis), encompasses students' aptitude to determine connections between variables, construct data, and critically assess evidence. Lastly, the fifth indicator, conclusion drawing (Facione-Inference), measures students' proficiency in combining findings and constructing rational conclusions derived from their analytical results.

Context 1: *Kidneys possess remarkable capabilities in filtering blood and regulating fluid equilibrium. Nevertheless, an athlete suffers from dehydration during exercise in elevated temperatures. Fatigue and discomfort arise as the kidneys must exert greater effort to preserve remaining fluids. Under these circumstances, the filtration mechanism becomes less effective, potentially leading to toxic substance buildup in the body.*

Indicator 1 (Formulating Questions): *Using the details provided above, create one research question suitable for further investigation.*

Indicator 2 (Formulating Hypotheses): *Drawing from the information presented above, develop a hypothesis that could undergo testing.*

Context 2: *Extreme dehydration may compromise the kidneys' capacity to process blood and eliminate metabolic waste.*

Indicator 3 (Self-Regulation): *Given the scenario described above, what measures would you implement to preserve your kidney function?*

Context 3: *An experiment was conducted to test the hypothesis "The amount of water consumed by athletes affects the volume of urine produced by the kidneys." Three subjects each drank different quantities of water (100 ml, 300 ml, and 500 ml) simultaneously. After waiting one hour, they collected their urine in separate measuring containers, and the volumes were recorded as follows:*

Volunteer	Water Drunk (ml)	Urine Produced (ml)
A	100 ml	50 ml
B	300 ml	150 ml
C	500 ml	300 ml

Indicator 4 (Analyzing): *Using the data presented above, examine the relationship between water intake and urine output.*

Indicator 5 (Drawing Conclusions): *Drawing from your examination, formulate a conclusion regarding the kidneys' function in regulating bodily fluid equilibrium.*

Both assessment tools underwent expert validation to confirm their alignment with the research goals and context. Additionally, a preliminary trial of the critical thinking assessment was performed to evaluate validity and reliability. Validity testing results indicated that all items had r-values exceeding the r-table threshold (0.3610), confirming each item's validity. The reliability test yielded a Cronbach's Alpha of 0.950, indicating very high internal consistency and confirming that the instrument is reliable and appropriate for assessing students' critical thinking skills.

Data Analysis

The collected data were analyzed in several stages. In the initial phase, a descriptive qualitative examination was conducted to provide an overview of student responses and collective learning outcomes. Subsequently, tests for normality and homogeneity were performed to determine whether the data met the prerequisites for parametric testing. Upon establishing data appropriateness, a paired-samples t-test was used to evaluate the significance of progress within individual groups by comparing their pre-test and post-test scores. Lastly, an independent-samples t-test was conducted to determine whether a statistically significant difference existed between the experimental and control groups following SQ-SW implementation. These analytical procedures were designed to establish the efficacy of Socratic Questioning-based worksheets in improving students' critical thinking competencies relative to traditional instructional approaches.

▪ RESULT AND DISSCUSSION

Student Worksheets based on Socratic Questioning (SQ-SW) were developed to enhance critical thinking by using carefully structured, thought-provoking questions. These queries guide learners to examine concepts more deeply, challenge their assumptions, and explore diverse perspectives. In this study, the effect of SQ-SW implementation was investigated in three aspects: (1) implementation of learning, (2) improvement of critical thinking skills before and after treatment, and (3) differences between the experimental and control groups. The implementation of learning describes students' responses in using SQ-SW in science learning in the classroom. The results of the analysis of learning implementation are presented in Table 1.

Table 1. Student response to SQ-SW learning

No.	Statements	Score	Category
1.	I feel more actively involved in the learning process using SQ-SW.	84	VG
2.	I often feel like I do not actively participate during learning with SQ-SW.	8	NG
3.	I find it difficult to participate in group discussions when using SQ-SW	11	NG
4.	SQ-SW encourages me to express ideas and opinions more often.	86	VG
5.	I feel more enthusiastic about participating in learning using	89	VG
6.	SQ-SW helps me better understand the material on the excretory system.	91	VG
7.	SQ-SW is confusing and does not help me understand the excretory system.	10	NG
8.	I often have trouble understanding materials even though I use SQ-SW.	11	NG
9.	I understand excretory organs function better after using SQ-SW.	81	VG
10.	Materials in SQ-SW are easy to understand and help me master important concepts.	88	VG
11.	SQ-SW helps me formulate the right questions regarding the material being studied.	94	VG
12.	SQ-SW does not help me in finding effective solutions to the problem discussed.	11	NG
13.	I cannot properly regulate myself in completing tasks using SQ-SW.	14	NG
14.	SQ-SW helps me to analyze information more thoroughly before drawing a conclusion.	91	VG
15.	I was able to conclude the material better after using SQ-SW ini.	93	VG
16.	Learning with SQ-SW makes the learning process more fun	91	VG
17.	I am not satisfied with the Socratic questioning method used in the student worksheet.	12	NG
18.	Learning with SQ-SW feels boring and ineffective	8	NG
19.	I am happy with the way I learned using SQ-SW, which encourages deep discussion	94	VG
20.	I feel the Socratic questioning method is too difficult to apply in this learning.	9	NG
21.	I feel that I can work well together when using SQ-SW.	93	VG
22.	I find it challenging to work together in a group when using SQ-SW.	11	NG
23.	SQ-SW does not encourage good cooperation in the group.	11	NG
24.	Group discussion when using SQ-SW was ineffective.	12	NG
25.	I feel comfortable sharing opinions and ideas with group members when using SQ-SW.	91	VG
26.	I manage my time well while working on SQ-SW.	89	VG
27.	I cannot finish SQ-SW within the given time.	9	NG
28.	SQ-SW was too time-consuming and made it difficult for me to manage my study time.	11	NG
29.	Use of time in learning with SQ-SW feels effective.	91	VG
30.	I feel like I cannot manage my time well when working in the group using SQ-SW.	8	NG

Note: VG = Very good, NG = Not Good

Based on Table 1, all positive statements received very good responses, while all negative statements received poor responses. In other words, students responded positively to SQ-SW-based learning activities. These responses are summarized in Figure 1.

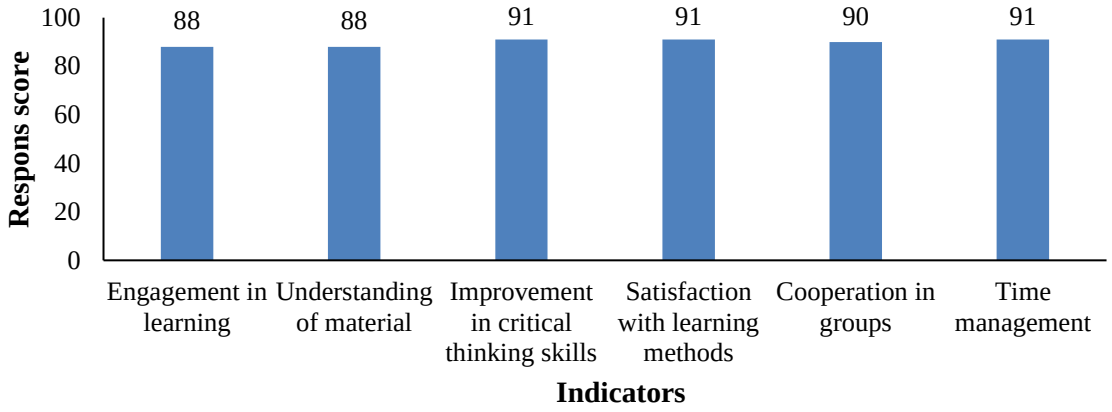

Figure 2. Student response to SQ-SW learning

Based on Figure 2, SQ-SW can be implemented effectively. Students felt more engaged, had a better understanding of the material, and could actively participate in both group and independent activities. This encouraging response pattern illustrates various mechanisms behind SQ-SW's effectiveness in this investigation: (1) Enhanced student participation: SQ-SW prompted students to take an active role and voice their perspectives during collaborative exchanges, (2) Enhanced conceptual understanding: The SQ-SW approach strengthened students' knowledge of the excretory system through hands-on activities that connected theoretical knowledge with real-world applications, (3) Development of critical thinking skills: The worksheet guided students in formulating questions, developing hypotheses, analyzing information, and drawing logical conclusions, and (4) Enhanced collaboration and self-regulation: Students being able to cooperate effectively and manage their study time well. Though some students initially struggled with higher-level questions, the progressive, organized practice helped develop their reflective and analytical skills. This result aligns with the findings of Aribah et al. (2025), who emphasized that Socratic questioning creates more reflective learning opportunities and deepens conceptual comprehension. The value of this research lies in embedding Socratic questions throughout the worksheet design, which empowered students to develop critical thinking skills during collaboration and self-directed learning. Moreover, the impact of SQ-SW is validated by comparing N-Gain differences in critical thinking abilities between experimental and control classes, as displayed in Table 2.

Table 2. Critical thinking N-Gain for the experimental and control group

Indicator	Experimental				Control			
	Pre-test	Post-test	N-Gain	Category	Pretest	Post-test	N-Gain	Category
Formulating question	28.75	75.31	0.65	Medium	27.81	35.31	0.10	Low

Formulating hypotheses	44.37	80.62	0.65	Medium	57.18	58.43	0.02	Low
Self-Regulation	52.50	84.37	0.67	Medium	57.18	66.56	0.21	Low
Analysis	58.12	68.43	0.24	Low	52.81	59.06	0.13	Low
Drawing conclusion	38.43	69.37	0.50	Medium	26.87	38.75	0.16	Low
Average	**44.44**	**75.63**	**0.56**	**Medium**	**44.38**	**51.63**	**0.11**	**Low**

Based on Table 2, all indicators of critical thinking in the experimental group improved, though to varying degrees. Self-regulation showed the most significant improvement (0.67), with question formulation and hypothesis development close behind (both at 0.65), while conclusion-drawing demonstrated moderate growth (0.50). However, the analysis indicator showed the lowest improvement (0.24).

These results reveal that the SQ-SW has varying degrees of impact across different dimensions of critical thinking. The strong performance noted in self-regulation and hypothesis formulation indicators can be attributed to the worksheet's structure, which prioritizes reflective exercises and assumption testing. For example, in the "Formulating Hypothesis" segment, learners are prompted to compose a preliminary hypothesis, such as "What is the relationship between salt concentration in water and the volume of water left following filtration?" before examining observational evidence. After the group discussion and result comparison, students modify their hypotheses based on the collected data. This process directly trains their cognitive self-regulation, rational thinking, and habit of testing the validity of arguments before concluding.

A concrete example of this development can be seen in students' answers before and after the intervention. Before the learning activity, some students wrote general hypotheses such as "The amount of remaining water will not change." After using the SQ-SW, their responses became more argumentative and specific, for example, "The higher the concentration of salt added, the smaller the volume of water remaining after the filtration process. This illustrates the working principle of the kidneys in filtering blood and excreting metabolic waste." This shift indicates an improvement in students' critical thinking skills, particularly in hypothesis formulation and self-regulation, as they not only provided answers but also connected their observations with relevant physiological concepts and revised their thinking based on the evidence obtained.

On the other hand, the modest advancement in the analysis indicator indicates that this area needs more targeted support. A likely contributing factor concerns the nature of the questions embedded in the SQ-SW worksheet, which remained within guided inquiry parameters and did not fully prompt students to evaluate data side-by-side, spot patterns, or derive insights from varied information sources. In addition, several students appeared to have difficulty connecting the results of observations related to excretory processes, indicating the need for additional scaffolding in the form of more analytical guiding questions, such as "*How does this experiment reflect the filtration process in the human kidney?*" Thus, although the SQ-SW is effective in enhancing overall critical thinking abilities, the analytical dimension still needs further development, whether through data-comparison exercises or more thorough reflection, enabling students to build more robust analytical skills.

However, overall, the experimental class's average N-Gain was still in the medium range, indicating that, in general, the application of SQ-SW continued to improve students' critical thinking skills. On the other hand, the control class shows only an increase in the low category for each indicator. To better understand the extent of SQ-SW's impact on students' critical thinking, researchers conducted an effect-size analysis. This enables a more nuanced interpretation of how the intervention performed, extending beyond N-Gain measurements.

Table 3. Effect size of critical thinking (Cohen's d)

Indicator	Effect Size	Category
Formulating question	0.642	Large
Formulating hypotheses	0.328	Medium
Self-Regulation	0.326	Medium
Analysis	0.116	Small
Drawing conclusion	0.548	Large
Average	**0.392**	**Medium**

Based on Table 3, the effect of SQ-SW in the experimental group is considered large for two of five indicators (formulating questions and drawing conclusions) and medium for two others (formulating hypotheses and self-regulation). The analysis indicator shows a small effect, consistent with previous N-Gain findings. Meanwhile, in the control group, the effect size is relatively low (small). These results confirm that implementing SQ-SW significantly improves students' critical thinking skills.

Furthermore, to determine the significance of increasing critical thinking, a statistical test will be conducted. However, before that, the test begins with normality and homogeneity tests. The results of the normality test with the Kolmogorov-Smirnov statistic were significant in the Pre-test (Control), Post-test (Control), Pre-test (Experiment), and Post-test (Experiment) values of .177, .095, 0.111, and .176, respectively. This means that all the data is normally distributed. In addition, the results of the Levene test for the experimental and control classes yielded sig values of 0.697 and 0.170, indicating that the data are homogeneously distributed. Thus, the statistical test uses a paired-samples t-test, with results presented in Table 4.

Table 4. Paired sample T-Test

Paired Samples Test							
		Paired Differences			*t*	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	PreControl - PostControl	-7.250	9.939	1.757	-4.127	31	.000
Pair 2	PreExperimen - PostExperimen	-31.188	10.751	1.900	-16.410	31	.000

Based on Table 4, it is known that the significance value (Sig. 2-tailed) in both groups is 0.000 or $p < 0.05$. This shows a significant improvement in critical thinking skills between pre-test and post-test scores in both the control and experimental classes. However, the level of improvement in critical thinking skills in the experimental class

was much higher than in the control class. This shows that SQ-SW is more effective at improving students' critical thinking skills than conventional learning methods.

The notable progress observed in the experimental classroom stems from the deliberate embedding of Socratic questioning throughout the SQ-SW. Particular prompts within the worksheet were designed to address distinct dimensions of critical thinking:

1. Formulating questions & hypotheses: Questions including "*What do you see happening with water volume as salt concentration changes?*" Moreover, "*What initial ideas do you have about the salt-water relationship in this investigation?*" stimulated students to create hypotheses and formulate new questions.
2. Analysis: Probes like "*What accounts for the water level difference after salt removal?*" and "*How do your observations support this interpretation?*" helped students analyze their data more carefully, link evidence to scientific principles, and interpret what their results meant.
3. Self-regulation: Probing questions like "*How might you characterize the way salt affects the water left behind?*" Moreover, "*What distinguishes the results when more salt is added?*" required students to monitor their thinking, organize information, and evaluate patterns in the data.
4. Drawing conclusions & perspective: Probing questions like "*Are these findings applicable to kidney mechanisms in humans?*" And "*What would be the impact if bodily waste removal became ineffective?*" enabled learners to connect theoretical principles with observational data, supporting the development of considered conclusions.

By progressively scaffolding students through questioning, hypothesizing, self-regulation, analysis, and inference, SQ-SW effectively improves their critical thinking skills across most indicators. This evidence validates Picciano's assertion in Siagian et al. (2023) regarding the efficacy of Socratic Questioning as an approach to sharpen students' critical thinking abilities. In addition, the study reinforces Arianti & Kusairi's (2020) findings that Socratic questioning significantly improves critical thinking skills compared to conventional methods.

The outcomes of this study both corroborate what Picciano suggested in Siagian et al. (2023) and what Arianti & Kusairi (2020) revealed, and further build on this work by demonstrating that incorporating Socratic questions into well-designed worksheets (SQ-SW) provides students with consistent guidance across question formulation, hypothesis development, self-directed learning, data analysis, and conclusion formation. Earlier studies typically employed Socratic questioning either orally or without systematic implementation. In contrast, this research demonstrates that integrating it within worksheet formats creates a stepped, continuous learning framework that produces observable gains in various critical thinking areas. This clarification highlights that SQ-SW goes beyond merely increasing student participation; it cultivates deeper analytical and reflective thinking, especially when dealing with complex, abstract scientific topics such as the excretory system.

When indicators break down the results, the experimental class showed moderate improvement in four of the five areas of critical thinking: formulating questions, formulating hypotheses, self-regulation, and concluding. However, in the analysis indicator, the increase is still relatively low. These findings are in line with the study by

Fiirdaus et al. (2021). This confirms that building analytical skills requires students to tackle challenging cognitive activities and practice regularly over time. Overall, SQ-SW encourages learners to think more deeply, evaluate information critically, and draw well-reasoned conclusions. This shows that the four main problems in this study, low critical thinking skills, material complexity, a monotonous learning process, and student passivity, can be overcome through the application of SQ-SW. This success was reinforced by the independent t-test results on critical thinking between the experimental and control classes, presented in Table 5.

Table 5. Independent sample T-Test

Independent Samples Test						
		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	*t*	df	Sig. (2-tailed)
KBK	*Equal variances assumed*	1.929	.170	10.131	62	.000
	Equal variances not assumed.			10.131	59.212	.000

Based on Table 5, it is known that the significance value (Sig. 2-tailed) in the independent sample t-test is 0.000 or $p < 0.05$. This shows a significant difference in students' critical thinking skills between the experimental and control classes. Students who used SQ-SW demonstrated better critical thinking skills than those who used a conventional student worksheet. This difference is reflected not only in the post-test results but also in the learning process itself. The experimental group demonstrated a more dynamic, interactive, and contemplative learning environment, whereas the control group continued to employ conventional teacher-led instruction. This aligns with the research of Arianti & Kusairi (2020), who demonstrated that Socratic questioning techniques effectively enhance students' critical thinking abilities. Nevertheless, the research revealed certain limitations, particularly regarding the analysis indicators that showed comparatively weak performance. This indicates that while Socratic questioning benefits most critical thinking indicators, additional emphasis on developing comprehensive information analysis skills remains necessary. Therefore, future use of student worksheets is suggested to place more emphasis on analytical activities, such as comparing data, identifying patterns, and systematically evaluating arguments.

Based on the study's findings (Tables 1-5), the application of SQ-SW significantly improves students' critical thinking skills in excretory system materials. The results of this study reinforce the Socratic questioning theory, which emphasizes the importance of the questioning process as a strategy to encourage students to think critically, evaluate information, and build deeper understanding. Through a multi-level question process, students are encouraged to develop logical reasoning, clarify their ideas, and consider various points of view. In addition, the results of this study strengthen the definitions of critical thinking skills by Facione, thinking aim to prove, interpret, and solve problems, and by Ennis, the ability to make rational decisions regarding what to do or believe. In practice, this study suggests that SQ-SW is an effective learning strategy for improving junior high school students' critical thinking skills, especially when dealing with complex materials such as the excretory system.

▪ CONCLUSION

The application of SQ-SW significantly improves students' critical thinking skills in excretory system materials. Socratic questioning activities in student worksheets can be applied effectively in learning. In addition, there was a significant improvement in students' critical thinking skills before and after learning, and a significant difference between the experimental and control classes, with the experimental class (n-gain = 0.56) showing a larger improvement than the control class (n-gain = 0.11). The findings of this study point to the need for follow-up investigations to test SQ-SW across different science content areas, with priority given to challenging and theoretical topics such as how the human body functions at a physiological level. Furthermore, implementation should encompass learners at various educational stages to explore whether this systematic, layered methodology reliably strengthens critical thinking components such as question formulation, hypothesis development, self-monitoring, analytical reasoning, and conclusion formation. Broadening the research parameters in this way would yield stronger empirical support regarding the efficacy and versatility of SQ-SW as an instructional approach.

▪ REFERENCES

Alharbi, S. M., Elfeky, A. I., & Ahmed, E. S. (2022). The effect of e-collaborative learning environment on the development of critical thinking and higher-order thinking skills. *Journal of Positive School Psychology*, *6*, 6849. http://journalppw.com

Arianti, S., & Kusairi, S. (2020). *Kemampuan berpikir kritis siswa pada pembelajaran structured inquiry berbantuan socratic questioning : materi optika geometri* [Students' critical thinking skills in structured inquiry learning assisted by Socratic questioning: geometric optics material]. *Jurnal Riset Pendidikan Fisika*, *5*(1), 30–37. http://journal2.um.ac.id/index.php/jrpf/article/view/15907

Aribah, L., Sabarudin, & Rofik. (2025). *Analisis persepsi mahasiswa terhadap efektivitas strategi pembelajaran socratic questioning dalam meningkatkan keterampilan berpikir kritis* [Analysis of students' perceptions of the effectiveness of the Socratic questioning learning strategy in improving . *Dimar; Jurnal Pendidikan Islam*, *6*(2), 199. https://doi.org/10.58577/dimar.v6i2.339

Ayunda, N., Lufri, & Alberida, H. (2023). *Pengaruh model pembelajaran problem based learning (PBL) berbantuan LKPD terhadap kemampuan berpikir kritis peserta didik* [The influence of the problem based learning (PBL) learning model assisted by LKPD on students' critical thinking skills]. *Journal on Education*, *5*(2), 5003–5004. https://doi.org/10.31004/joe.v5i2.1232

Bangun, A. V., & Pragholapati, A. (2021). Enhancing critical thinking skills in nursing higher education in preparation for the industrial revolution 4.0. *KnE Life Sciences*, *2021*(1), 794. https://doi.org/10.18502/kls.v6i1.8756

Blyznyuk, T., & Kachak, T. (2024). Benefits of interactive Learning for students' critical thinking skills improvement. *Journal of Vasyl Stefanyk Precarpathian National University*, *11*(1), 94–95. https://doi.org/10.15330/jpnu.11.1.94-102

Descartin, D. M. D., Kilag, O. K. T., Groenewald, S. E., Abella, J. L., Cordova Jr, N. A., & Jumalon, M. L. S. (2023). Curricular insights: Exploring the impact of philippine k to 12 on PISA 2022 reading literacy achievement. *Excellencia International*

Multi-Disciplinary Journal of Education, *1*(6), 335. https://orcid.org/0009-0003-0939-2899

Favero, L., Pérez-Ortiz, J. A., Käser, T., & Oliver, N. (2025). *Enhancing critical thinking in education by means of a socratic chatbot*. *17*(32), 2. https://doi.org/10.1007/978-3-031-93409-4_2

Fiirdaus, R. J., Wahyuni, S., & Utomo, A. P. (2021). *Analisis penggunaan video pembelajaran ipa kontekstual terhadap kemampuan berpikir kritis siswa SMP* [Analysis of the use of contextual science learning videos on the critical thinking skills of junior high school students]. *Physics and Science Education Journal (PSEJ)*, *1*(2), 54. https://doi.org/10.30631/psej.v1i2.702

Ghaleb, B. D. S. (2024). Effect of exam-focused and teacher-centered education systems on students' cognitive and psychological competencies. *International Journal of Multidisciplinary Approach Research and Science*, *2*(02), 612. https://doi.org/10.59653/ijmars.v2i02.648

Ho, Y. R., Chen, B. Y., & Li, C. M. (2023). Thinking more wisely: using the socratic method to develop critical thinking skills amongst healthcare students. *BMC Medical Education*, *23*(1), 1–16. https://doi.org/10.1186/s12909-023-04134-2

Hu, Z. (2023). Promoting critical thinking through socratic questions in health sciences work-integrated learning. *International Journal of Learning, Teaching and Educational Research*, *22*(6), 139. https://doi.org/10.26803/ijlter.22.6.8

Kooloos, J. G. M., Bergman, E. M., Scheffers, M. A. G. P., Schepens-Franke, A. N., & Vorstenbosch, M. A. T. M. (2020). The effect of passive and active education methods applied in repetition activities on the retention of anatomical knowledge. *Anatomical Sciences Education*, *13*(4), 458–460. https://doi.org/10.1002/ase.1924

Li, S., Tang, S., Geng, X., & Liu, Q. (2022). Constructing a critical thinking evaluation framework for college students majoring in the humanities. *Frontiers in Psychology*, *13*(November), 02. https://doi.org/10.3389/fpsyg.2022.1017885

Lintangsari, A. P., Emaliana, I., & Kusumawardani, I. N. (2022). Improving learners' critical thinking and learning engagement through socratic questioning in nominal group technique. *Studies in English Language and Education*, *9*(2), 705–708. https://doi.org/10.24815/siele.v9i2.22352

Norillah, Idris, R. G., Hidayah, N., & Niazi, J. A. (2022). Socratic questioning: a philosophical approach in developing critical thinking skills. *Al Hikmah International Journal*, *5*(4), 146. https://doi.org/https://doi.org/10.46722/hikmah.y5i4g

O'Reilly, C., Devitt, A., & Hayes, N. (2022). Critical thinking in the preschool classroom - A systematic literature review. *Thinking Skills and Creativity*, *46*(August), 2. https://doi.org/10.1016/j.tsc.2022.101110

Ragab, A., Kaid, A., & Sayed, A. K. (2024). Enhancing higher order thinking skills (HOTS) in education: strategies and outcomes. *The Future of Education Journal*, *3*(5), 1489. https://journal.tofedu.or.id/index.php/journal/index

Ristanto, R. H., Rahayu, S., & Mutmainah, S. (2021). Conceptual understanding of excretory system: implementing cooperative integrated reading and composition based on scientific approach. *Participatory Educational Research*, *8*(1), 30–31. https://doi.org/10.17275/per.21.2.8.1

Rubini, B., Septian, B., & Permana, I. (2019). Enhancing critical thinking through the

science learning on using interactive problem based module. *Journal of Physics: Conference Series, 1157*(2), 1. https://doi.org/10.1088/1742-6596/1157/2/022001

Siagian, B. E., Aziz, T. A., & Hakim, L. El. (2023). Implementasi metode Socrates di era pendidikan modern [Implementation of the Socratic method in the modern education era]. *Griya Journal of Mathematics Education and Application*, *3*(1), 188–191. https://doi.org/10.29303/griya.v3i1.289

Susanto, T. T. D., Solihin, R. R., Fauziyah, E. P., Yanti, N. V. I., & Ramadhania, A. P. (2024). *Upaya pemerintah Indonesia dalam meningkatkan kualitas guru ditinjau dari hasil PISA 2022: sebuah kajian pustaka* [The Indonesian government's efforts to improve teacher quality as reviewed from the results of PISA 2022: a literature review]. *Perspektif Ilmu Pendidikan*, *38*(1), 57–59. https://doi.org/10.21009/pip.381.6

Suyidno, Nur, M., Yuanita, L., & Salam, A. (2020). *Creative responsibility based learning*. Lambung Mangkurat University Press.

Thornhill-Miller, B., Camarda, A., Mercier, M., Burkhardt, J. M., Morisseau, T., Bourgeois-Bougrine, S., Vinchon, F., El Hayek, S., Augereau-Landais, M., Mourey, F., Feybesse, C., Sundquist, D., & Lubart, T. (2023). Creativity, critical thinking, communication, and collaboration: assessment, certification, and promotion of 21st century skills for the future of work and education. *Journal of Intelligence, 11*(3), 1. https://doi.org/10.3390/jintelligence11030054