

Improving Students' Critical Thinking Skills Using Guided Inquiry with Problem-Solving Process

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Abstract

High-level thinking skills known as critical thinking are deemed essential for students in the contemporary era to equip them for the challenges ahead. However, current research suggests that students' proficiency in critical thinking remains relatively insufficient. This research endeavors to explore how the application of guided inquiry combined with problem-solving techniques influences the critical thinking abilities of 11th-grade students. Carried out in a public high school situated in Jakarta, Indonesia, this quantitative study involved seventy-two students chosen as participants. Employing a quasi-experimental approach, two intact classes were enlisted and randomly assigned as either the experimental group (n=36) or the control group (n=36). Data were collected through an essay test assessing critical thinking skills and were subsequently analyzed using independent and paired sample t-tests. Results revealed a positive impact of guided inquiry supplemented with problem-solving techniques on students' critical thinking capabilities. Consequently, it can be deduced that this instructional method effectively enhances students' critical thinking skills. The findings recommend educators adopt guided inquiry coupled with problem-solving strategies to cultivate students' critical thinking abilities to a satisfactory level.

Keywords: *Problem-Solving Process, Chemistry, Critical Thinking Skills, Guided Inquiry*

INTRODUCTION

In the twenty-first century, educational emphasis has shifted towards honing students' abilities. According to Garcia et al. (2020), contemporary learning prioritizes a student-centric approach where the teacher relinquishes the central role in the classroom, instead fostering an environment for active student engagement and expression of opinions. This student-centered approach aims to cultivate high-level thinking skills among students. High-level thinking skills encompass cognitive abilities involved in recalling, summarizing, or referencing information. These skills, categorized as higher-order thinking skills within the framework of 21st-century skills, are deemed crucial for students to prepare for their future (Lu et al., 2021). Hwang et al. (2017) delineated three key higher-order thinking skills: problem-solving, creativity, and critical thinking. Among these, critical thinking stands out as a fundamental skill requisite for navigating 21st-century society (Santos-Meneses & Drugova, 2023). Critical thinking denotes the capacity to impartially analyze information, think logically and coherently, and render reasoned judgments. It is regarded as reflective thinking that centers on determining beliefs or courses of action (Ennis, 2011). In essence, these skills are indispensable for students to effectively apply, assess, and make informed decisions based on gathered information (Van Brederode et al., 2020).

Critical thinking skills play a pivotal role in fostering students' cognitive growth. Prior research has highlighted a positive relationship between critical thinking skills and various academic facets, including academic achievement (Ghanizadeh, 2017), creative thinking (Chang et al., 2015), logical thinking (Incikabi et al., 2013), and metacognitive comprehension (Schraw et al., 2006). Consequently, enhancing students' critical thinking abilities has emerged as a primary objective for researchers and educators worldwide. Regrettably, extant studies indicate that students often exhibit subpar levels of critical thinking skills. For instance, research conducted by Gültepe and Kılıç (2021) in Turkey revealed that students' critical thinking skills remain notably underdeveloped. Similarly, in China, Fan and See (2022) observed that students frequently resorted to mere regurgitation of recently taught material when asked to draw conclusions at the conclusion of a lesson.

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Comparable findings were also reported in the Indonesian context by Andayani et al. (2020). This deficiency in students' critical thinking abilities may be attributed to the prevalent use of instructional methods that fail to prioritize student engagement and autonomy.

In science education, inquiry-based learning has emerged as a promising pedagogical approach (Orosz et al., 2023). This is primarily because science learning inherently involves hands-on activities that necessitate problem-solving and critical thinking skills, all of which are effectively fostered through an inquiry-based methodology. Previous research underscores that inquiry-based learning fosters active engagement by involving students in the learning process and empowering them to explore learning materials independently (Loertscher & Minderhout, 2019). Moreover, Katchevich et al. (2013) found that employing an inquiry-based approach aids students in formulating arguments throughout various stages, including hypothesis formulation, analysis, and drawing appropriate conclusions.

Aside from inquiry-based learning, another effective strategy for cultivating students' thinking abilities is problem-solving (Vo et al., 2022). Problem-solving lies at the heart of problem-based learning, which aims to equip students with the skills to tackle real-life challenges. According to Ozturk and Guven (2016), engaging in the problem-solving process enables students to not only resolve issues but also to organize information meaningfully, fostering independence and self-confidence. In the current study, researchers employed a combination of guided inquiry and problem-solving processes to elicit a potent impact. Guided inquiry learning enables students to construct knowledge through experimentation, thought processes, and inquiry, while the problem-solving process encourages active engagement and critical thinking (Tornee et al., 2019). By integrating guided inquiry with problem-solving, the study aimed to provide students with valuable experiences in identifying and resolving issues. Consequently, the research question posed in this study is: "Does the implementation of guided inquiry with problem-solving processes have an effect on students' critical thinking skills?"

LITERATURE REVIEW

Critical Thinking Skills (CTS)

CTS encompasses cognitive processes wherein individuals actively and adeptly conceptualize, apply, analyze, synthesize, or evaluate information garnered from observation, reasoning, experience, or reflection. These skills serve as a compass for determining attitudes and actions (Allen, 2008). However, the development of critical thinking skills is not spontaneous but rather a gradual process (Guo, 2016). Critical thinking entails a methodical approach that affords students the opportunity to assess conclusions based on evidence (Eggen & Kauchak, 2012). As described by Gagne, critical thinking involves the ability to scrutinize information, ascertain its relevance, and then interpret it to resolve problems (Rodzalan & Saat, 2015). It necessitates the interpretation and evaluation of observations, communications, and various information sources. Furthermore, it demands proficiency in scrutinizing assumptions, posing pertinent questions, drawing implications, and engaging in continuous deliberation on issues (Fisher, 2007). Critical thinking is considered a foundational skill alongside reading and writing within the international education community (Wan et al., 2023). It serves as a catalyst for inquiry, exploration, and the creation of knowledge, fostering rational thought processes.

Guided Inquiry with Problem-Solving Process

Incorporating guided inquiry with a problem-solving process underscores the active involvement of students in the learning process. Guided inquiry entails a sequence of educational activities designed to engage students in systematic, critical, logical, and analytical exploration, enabling them to confidently formulate their own conclusions (Orosz et al., 2023). The primary objective of guided inquiry learning activities is to fully engage students in the teaching and learning process, guiding their activities in a logical and systematic manner toward defined learning objectives, and instilling in them a sense of confidence in their findings throughout the inquiry process.

Less active students may encounter challenges in grasping concepts and honing their critical thinking skills. Additionally, students who rely on rote memorization without understanding the underlying processes may

struggle to apply their knowledge to problem-solving situations. Hence, integrating inquiry-based learning with other instructional methods becomes imperative to enhance effectiveness and optimize students' mastery of concepts, problem-solving abilities, and critical thinking skills. Problem-solving stands out as a type of learning with the potential to cultivate both activity and problem-solving skills (Molnár et al., 2013).

Problem-solving lies at the core of problem-based learning, where students are trained to tackle real-life challenges that they may encounter (Iglesia et al., 2015). As highlighted by Loibl and Rummel (2017), the essence of problem-solving lies in its potential to enable students to resolve problems, thereby facilitating the construction of more meaningful knowledge and fostering independence and self-confidence. Positioned as an effective complement or alternative to inquiry-based learning (Bunterm et al., 2014), problem-solving offers students opportunities to actively engage in exploring knowledge, formulating problems, observing, investigating, and devising solutions within a guided inquiry framework supplemented by problem-solving processes.

RESEARCH METHODOLOGY

Research Design

To accomplish our objective, our research employed a quasi-experimental nonequivalent control group design. Experimental research aims to ascertain whether specific interventions impact study outcomes (Creswell, 2012). In order to discern the learning method that exerts a significant influence on critical thinking skills, we compared the mean scores of the experimental group, which received instruction using guided inquiry supplemented by a problem-solving process, with those of the control group, which was taught using the think-pair-share cooperative learning approach.

Participants

The study involved 72 grade 11 students, comprising 28 males and 44 females, enrolled in a chemistry course at a state senior high school during the academic year 2022/2023. The experimental group (EG) comprised 36 students, consisting of 14 males and 22 females, with ages ranging from 16 to 17 years. Similarly, the control group (CG) also consisted of 36 students, with 14 males and 22 females, aged between 16 and 18 years. One of the classes was randomly assigned as the EG, while the other served as the CG. Both groups exhibited nearly identical characteristics.

Research Instrument

The instrument utilized in this study was the Critical Thinking Essay Test (CTET), comprising 9 items. The minimum score obtained on each question is 0 and the maximum score is 4. Students took 90 minutes to complete the test. The CTET covered 5 indicators; problem identification, conceptual understanding, ideas connection, assumptions, and inferences adapted from SCIT 1020 (2013). Prior to use, the CTET underwent validation and empirical testing, followed by an examination of its reliability. In the present study, the Cronbach's alpha coefficient for the CTET was $\alpha = 0.82$. This coefficient surpassed the acceptable threshold of 0.70 (Cohen et al., 2018), thus indicating that the CTET was deemed reliable for the study.

Procedure

Research permission was obtained on 6 February 2023 (reference number 3229/UN39.12/KM/2023). In the EG, the teacher explored students' prior knowledge by revealing everyday phenomena. The teacher organized students into 6 groups consisting of 6 students in each group. Then the teacher provided motivation to focus students' attention by presenting learning videos. The teacher then provided a worksheet and guided students to identify as many questions as possible related to the video about the concept and properties of buffer solutions. Then, the teacher guided students to propose hypotheses, encouraged students to collect data, and guided students in testing hypotheses. After that, students were requested to present the results of the discussion. Students were then asked to draw conclusions, present results, discuss findings, and exchange ideas. Finally, the teacher provided reinforcement. In the CG, the teacher asked a question about the properties of the buffer solution through a worksheet, and then organized the students to pair up with their classmates. After

that, the teacher called students to present the results of the discussion. Students in other groups were asked to listen and take notes.

Data Analysis

The study's data were derived from the Critical Thinking Essay Test (CTET). Descriptive statistics were employed to characterize the data, including mean scores, standard deviations, and minimum and maximum scores. Kolmogorov-Smirnov and Levene's tests were conducted to assess the assumptions of normality and homogeneity, respectively. Following the assumption tests, the data from both the pretest and posttest for critical thinking skills (CTS) exhibited a normal and homogeneous distribution ($p > 0.05$). Consequently, the data were suitable for analysis using *t*-tests. An independent samples *t*-test was utilized to ascertain whether statistically significant gaps existed in mean scores between the two sample groups. Additionally, a paired samples *t*-test was conducted to explore the impact of learning methods on students' CTS within each group. Furthermore, the effect size (*d*) was calculated to measure the magnitude of change in students' scores before and after treatment (Cohen et al., 2018). Cohen's *d* values elucidated the extent of the difference between pretest and posttest scores. Inferential analysis was conducted at a significance level of 0.05 using the statistical software SPSS 25.0.

RESULTS

Based on the analysis, the pretest score of the EG was slightly greater than the CG. Meanwhile, the average posttest score for both the CG and EG increased compared to their pretest score. In the CG, the average increase scores in pretest and posttest was from 1.54 to 2.87 (an increase of 1.33). Meanwhile, in the EG, the average increase in pretest and posttest scores was from 1.55 to 3.29 (an increase of 1.74). It can be observed that students in the EG showed a greater increase in CTS than the CG after treatment (see Table 1).

Table 1. Descriptive data of students' CTS between the two groups

Group		Pretest						Posttest					
		PI	CU	IC	As	In	All	PI	CU	IC	As	In	All
EG	M	1.60	1.43	1.19	1.93	1.58	1.55	3.24	3.49	3.21	3.36	3.14	3.29
	SD	0.44	0.36	0.55	0.68	0.69	0.34	0.60	0.53	0.53	0.47	0.72	0.41
	Min	1.00	1.00	0.50	0.50	0.00	1.22	2.00	2.50	2.00	2.50	2.00	2.56
	Max	2.50	2.00	2.00	3.00	3.00	2.33	4.00	4.00	4.00	4.00	4.00	4.00
CG	M	1.58	1.42	1.25	1.92	1.53	1.54	2.85	3.19	2.75	2.79	2.75	2.87
	SD	0.42	0.35	0.51	0.64	0.65	0.28	0.62	0.51	0.50	0.66	0.91	0.35
	Min	1.00	1.00	0.50	0.50	0.00	1.22	1.50	2.50	2.00	1.00	1.00	1.89
	Max	2.50	2.00	2.00	3.00	3.00	2.22	4.00	4.00	4.00	4.00	4.00	3.33

Note: PI: Problem identification; PU: Conceptual understanding; IC: Ideas connection; As: Assumptions; In: Inferences; All: All CTS indicators

The study utilized an independent *t*-test to investigate whether a significant disparity existed in pretest critical thinking skills (CTS) scores between the two groups. The results indicated that there was no statistically significant gap between students instructed using guided inquiry learning with a problem-solving process and those taught using cooperative learning ($t = -0.84$; $p = 0.934$). Furthermore, the gaps in scores across sub-indicators were not deemed statistically significant ($p > 0.05$). These findings suggest that all participants possessed similar levels of CTS at the outset of the learning process (see Table 2).

Table 2. The gaps in pretest CTS scores between the two groups

Indicator	Group	N	M	SD	<i>t</i>	<i>p</i>
Problem identification	CG	36	1.583	0.423	-0.136	0.892
	EG	36	1.597	0.444		
Conceptual understanding	CG	36	1.417	0.349	-0.166	0.869
	EG	36	1.431	0.362		
Ideas connection	CG	36	1.250	0.514	0.442	0.660
	EG	36	1.194	0.551		
Assumptions	CG	36	1.917	0.638	-0.90	0.929
	EG	36	1.931	0.678		
Inferences	CG	36	1.528	0.654	-0.350	0.727
	EG	36	1.583	0.692		
All indicators	CG	36	1.654	0.468	-0.84	0.934

Indicator	Group	N	M	SD	<i>t</i>	<i>p</i>
	EG	36	1.660	0.562		

The posttest scores between the CG and EG were significantly gap ($t = -4.550$; $p = 0.000$). Table 3 shows that the highest significance value is in the “Inferences” indicator and the smallest significance value is in the “Ideas connection” and “Assumptions” indicators. The results showed that guided inquiry with problem-solving process learning has been found effective in developing students’ CTS.

Table 3. The gaps in posttest CTS scores between the two groups

Indicator	Group	N	M	SD	<i>t</i>	<i>p</i>
Problem identification	CG	36	2.847	0.619	-2.699	0.009
	EG	36	3.236	0.603		
Conceptual understanding	CG	36	3.194	0.511	-2.383	0.020
	EG	36	3.486	0.528		
Ideas connection	CG	36	2.750	0.500	-3.789	0.000
	EG	36	3.208	0.526		
Assumptions	CG	36	2.792	0.659	-4.215	0.000
	EG	36	3.361	0.472		
Inferences	CG	36	2.750	0.906	-2.012	0.048
	EG	36	3.139	0.723		
All indicators	CG	36	2.879	0.385	-4.550	0.000
	EG	36	3.303	0.406		

The study further examined the comparison between students’ pretest and posttest Critical Thinking Skills (CTS) scores. A paired-sample *t*-test was utilized to determine any significant increase between pretest and posttest scores. Additionally, the effects of guided inquiry with the problem-solving process were quantified using Cohen’s *d*. The comparison of pretest and posttest scores on students’ CTS is presented in Table 4.

Table 4. Gaps between pretest and posttest scores on students’ CTS

Indicator	Group	N	Paired Differences		<i>t</i>	<i>p</i>	Cohen’s <i>d</i>
			M	SD			
Problem identification	CG	36	1.264	0.579	-13.092	0.000	2.38
	EG	36	1.639	0.556			
Conceptual understanding	CG	36	1.778	0.540	-19.737	0.000	4.06
	EG	36	2.056	0.475			
Ideas connection	CG	36	1.500	0.573	-15.701	0.000	2.96
	EG	36	2.014	0.485			
Assumptions	CG	36	1.917	0.840	-0.6251	0.000	1.35
	EG	36	1.430	0.600			
Inferences	CG	36	1.222	1.198	-6.122	0.000	1.55
	EG	36	1.556	0.773			
All indicators	CG	36	1.339	0.483	-16.625	0.000	3.96
	EG	36	1.760	0.354			

Based on the findings presented in Table 4, there is a notable and statistically significant increase in the mean scores of students’ critical thinking skills before and after the intervention ($p < 0.05$). In the CG, the indicator with the highest effect size is “Conceptual understanding,” whereas the indicator with the smallest effect size is “Assumptions.” Conversely, in the EG, the highest effect size is also observed in “Conceptual understanding,” while the smallest effect size is in “Inferences.” Cohen’s *d* values were calculated for overall CTS, yielding 3.96 for the CG and 4.69 for the EG. These results indicate that the effect size in the EG was greater than that in the CG.

DISCUSSION

This study investigated the impact of guided inquiry with a problem-solving process on students’ critical thinking skills regarding buffer solutions. Descriptive data revealed that students in the EG, after receiving the treatment, demonstrated more developed critical thinking skills compared to those in the CG. This indicates that guided inquiry with a problem-solving process positively influences students’ critical thinking skills on the topic of buffer solutions. These findings align with previous research conducted by Gupta et al. (2015), which also demonstrated the positive effect of guided inquiry on students’ critical thinking skills. Additionally, research by Tornee et al. (2019) corroborates these results by indicating that the combined use of guided inquiry and problem-solving processes has a beneficial impact on chemistry learning.

The findings indicated that there was no significant disparity between the pretest scores of the EG and CG. This suggests that prior to receiving treatment, both groups exhibited comparable levels of initial critical thinking skills. Furthermore, the results of the pretest underscored that conventional teaching methods had not effectively nurtured students' critical thinking skills. This observation aligns with research conducted by Van Brederode et al. (2020), which suggests that learning approaches that lean towards teacher-centered instruction may not adequately foster students' critical thinking abilities.

Throughout the treatment phase, students in the EG received instruction through guided inquiry supplemented by a problem-solving process, while those in the CG were taught using cooperative learning. The results revealed a significant improvement in critical thinking skills scores for both the experimental and control groups before and after the learning activities. This indicates that both guided inquiry learning with a problem-solving process and cooperative learning positively impact students' critical thinking skills. However, upon examining the effect size calculation, it was evident that the critical thinking skills of students in the EG exhibited a greater enhancement compared to those in the CG.

Students in the EG showed a higher increase in critical thinking skills scores compared to the CG. This is because students in the EG used a guided inquiry learning model combined with a problem-solving process. Learning through the guided inquiry model is deemed more meaningful as it affords students the opportunity to actively engage in discovering concepts via investigative activities, while also elucidating the relationships between objects and events in their environment under the guidance of the teacher (Sarioglan & Gedik, 2020; Koksal & Berberoglu, 2014). Research by Stender et al. (2018) supports this notion, suggesting that guided inquiry learning positively impacts students' conceptual understanding. Furthermore, studies such as that conducted by Azizmalayeri et al. (2012) have concluded that guided inquiry learning places significant emphasis on student collaboration in problem-solving tasks within group settings, thereby fostering independent knowledge construction.

Guided inquiry learning plays a pivotal role in fostering students' independence and accountability. Coupled with the problem-solving process, it equips students with essential skills for tackling challenges. Through the problem-solving process, students navigate stages such as problem comprehension, planning, implementation, and evaluation of solutions (Oztruk & Guven, 2016). This systematic approach not only deepens students' understanding of chemical concepts but also stimulates their analytical and critical thinking abilities (Bodner, 2015). Moreover, the amalgamation of guided inquiry with the problem-solving process has been demonstrated to positively impact science process skills, problem-solving capabilities, and cognitive function (Tornee et al., 2019). This underscores the significance of integrating these approaches to enhance students' learning outcomes and cognitive development in science education.

The improvement of critical thinking skills among EG students in this study is possible because during learning they are directly involved in the process of identifying and formulating problems. The process of identifying and formulating problems determines the direction or focus of learning activities. The process of identifying and formulating problems is a critical step in problem-solving (Avsec & Kocijancic, 2014). In the guided inquiry stage with the problem-solving process, students also formulate hypotheses or temporary answers to the problems that have been proposed. According to Dobber et al. (2017), formulating hypotheses can train critical thinking skills to analyze existing information and construct arguments. This helps students to better understand scientific thinking processes that are systematic and logical. Students collect relevant information to answer the questions that have been identified. Data collection helps students verify hypotheses or predictions that have been made before (Loertscher & Minderhout, 2019).

Then, students test hypotheses and identify assumptions. According to Ghanizadeh (2017), students use scientific reasoning skills to evaluate and interpret the data they have correctly. Students can think critically and analytically about the information or arguments provided. After that, students conclude the findings obtained during the learning process. Drawing conclusions allows students to connect previously learned concepts with the results of actual experiments or observations. By drawing conclusions, students must integrate various existing information and data to gain a deeper understanding of a topic. Drawing conclusions requires critical analysis of data and evaluation of results (Loes & Pascarella, 2017). Drawing conclusions can elevate students'

critical thinking skills in evaluating the information and evidence they have. Students then communicate the results of the discussion. Students ask questions or opinions if they find differences from the observations they meet. This can develop students' critical thinking skills by strengthening their conceptual understanding of the topic or problem being discussed. Indeed, the evaluation stage is crucial in the learning process. During this phase, students receive feedback and reinforcement, aiding in their comprehension of concepts and problem-solving abilities. Moreover, the evaluation stage serves to foster the development of critical thinking and problem-solving skills among students (Tornee et al., 2019). By reflecting on their performance and receiving constructive feedback, students can refine their understanding, identify areas for improvement, and enhance their overall learning experience. Thus, the evaluation stage plays a pivotal role in promoting deeper learning and skill development.

CONCLUSION

Based on the research results, the mean score of students' critical thinking skills in the pretest for the EG was 1.55 (SD = 0.34), while for the CG, it was 1.54 (SD = 0.28). In the posttest, the mean score of students' critical thinking skills increased to 3.29 (SD = 0.41) for the EG and to 2.87 (SD = 0.35) for the CG. The most significant improvement in students' critical thinking skills was observed in the "Conceptual understanding" indicator, attributed to their active involvement in exploration, discovery, and problem-solving processes. Additionally, Cohen's *d* value in the EG was greater than that of the CG, indicating that guided inquiry with a problem-solving process exerted a more pronounced positive influence on students' critical thinking skills. Therefore, it can be concluded that guided inquiry with a problem-solving process is effective in cultivating students' critical thinking skills.

This research encountered several limitations. Firstly, time constraints were a significant limitation as the research was conducted within only three sessions. Future studies could extend the duration of the intervention to gather more comprehensive findings. Secondly, the sample size was limited as only two intact classes, totaling 72 students, were involved in the study. It is suggested that future research employ a larger sample size to obtain more representative and generalizable results. Additionally, this study focused specifically on investigating the effect of guided inquiry with a problem-solving process on students' critical thinking skills pertaining to buffer solutions. Future research avenues could explore the impact of guided inquiry with problem-solving processes on other higher-order thinking skills and on different topics within the realm of chemistry. These recommendations aim to address and mitigate the limitations encountered in this study, thereby enhancing the robustness and applicability of future research findings.

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