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# The Effect of Guided Inquiry Assisted by eXe Learning on Critical Thinking and Learning Outcomes of Buffer Solution

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***Abstract***: *This study aimed to determine the effect of the Guided Inquiry learning model using eXe Learning media on students' critical thinking skills and learning outcomes on buffer solution material. The research was conducted at SMA Muhammadiyah 1 Medan in the odd semester of the 2024/2025 academic year. The population was all Grade XI IPA students. Purposive sampling was used to select two classes of 30 students each: the experimental class taught with Guided Inquiry eXe Learning and the control class taught with Direct Instruction eXe Learning. Data were collected through pretest-posttest (learning outcomes) and critical thinking tests. Prerequisite tests showed normal and homogeneous data. Data analysis used GLM Univariate and two-way ANOVA at α = 0.05. Results showed: (1) learning outcomes of students taught with Guided Inquiry eXe Learning were higher than those taught with Direct Instruction eXe Learning ($F = 4.378$; $p = 0.041$); (2) there was a significant difference in learning outcomes between high and low critical thinking students ($F = 4.642$; $p = 0.036$); and (3) there was a significant interaction between learning model and critical thinking level on learning outcomes ($F = 6.470$; $p < 0.05$). Guided Inquiry assisted by eXe Learning is more effective in improving chemistry learning outcomes, particularly for students with high critical thinking skills.*

***Keywords***: *Guided Inquiry; Exe Learning; Critical Thinking; Learning Outcomes; Buffer Solution*

## INTRODUCTION

Chemistry learning in senior high school aims to develop students' conceptual understanding, scientific process skills, and higher-order thinking skills, including critical thinking. Buffer solution is one of the topics that requires students to integrate conceptual knowledge of acid–base equilibrium with quantitative calculation and real-life application. However, many students still experience difficulties in understanding the working principle of buffer systems and in applying related formulas, which results in relatively low learning outcomes and limited critical thinking skills (Saraswaty et al., 2019; Ilahi et al., 2023).

Critical thinking is essential in chemistry education because it enables students to analyze problems, evaluate evidence, and draw reasoned conclusions.

Previous studies have shown that conventional teacher-centered approaches often fail to foster these skills adequately (Lee & Blanchard, 2019). Guided inquiry learning has been widely recommended as an alternative model that places students at the center of the learning process while still providing structured guidance from the teacher (Wenning, 2011). When combined with interactive digital media such as eXe Learning, the model can further support visualization, self-paced exploration, and active construction of knowledge.

Although several studies have examined guided inquiry or digital media separately in chemistry learning, research that simultaneously investigates the effect of guided inquiry assisted by eXe Learning on both critical thinking skills and learning outcomes—particularly on buffer solution material—and that employs a 2 × 2 factorial design remains limited. Most previous studies used one-group or simple pretest–posttest designs and did not examine the interaction between learning model and students' critical thinking level (Ilahi et al., 2023; Putri et al., 2025).

Therefore, this study aims to examine: (1) the difference in learning outcomes between students taught with Guided Inquiry + eXe Learning and those taught with Direct Instruction + eXe Learning; (2) the difference in learning outcomes between students with high and low critical thinking skills; and (3) the interaction effect between learning model and critical thinking level on students' chemistry learning outcomes on buffer solution material.

## LITERATURE REVIEW

Guided inquiry is a learning model in which students construct knowledge through a series of structured investigation activities under the guidance of the teacher. The typical syntax includes orientation, problem formulation, hypothesis formulation, data collection, analysis, and conclusion (Gulo, 2002; Suardana, 2007). This model has been shown to improve conceptual understanding, scientific process skills, and critical thinking on various chemistry topics, including buffer solutions (Saraswaty et al., 2019; Istyadji, 2023).

eXe Learning is an open-source authoring tool that allows teachers to create interactive learning packages containing text, images, simulations, quizzes, and hyperlinks without requiring advanced programming skills. The use of eXe Learning media can increase student engagement, support independent learning, and facilitate the visualization of abstract chemical concepts (Arsyad, 2008). When integrated with guided inquiry, eXe Learning provides a digital environment that guides students through the inquiry stages while allowing them to explore content at their own pace. Critical thinking skills involve interpretation, analysis, evaluation, inference, explanation, and self-regulation (Facione, 2011). In the context of buffer solution learning, students with higher critical thinking skills are expected to better understand equilibrium shifts, calculate pH changes, and relate the concept to everyday phenomena. Learning outcomes in this study are measured by normalized gain scores that reflect the improvement from pretest to posttest.

## METHODS

### *Research Design*

This research employed a quasi-experimental design with a 2 × 2 factorial arrangement. The independent variables were the learning model (Guided Inquiry eXe Learning vs. Direct Instruction eXe Learning) and the level of critical thinking skills (high vs. low). The dependent variable was the normalized gain of chemistry learning outcomes on buffer solution material.

### *Population and Sample*

The population consisted of all Grade XI IPA students of SMA Muhammadiyah 1 Medan in the odd semester of the 2024/2025 academic year.

Purposive sampling was used to select two classes, each consisting of 30 students. Class XI IPA 1 served as Experimental Class 1 (Guided Inquiry eXe Learning) and Class XI IPA 2 as Experimental Class 2 (Direct Instruction eXe Learning).

### *Instruments*

Learning outcomes were measured using a multiple-choice pretest and posttest on buffer solution material. Critical thinking skills were measured using a separate test administered during the learning process. Instrument validation included content validity, reliability (Cronbach's alpha), difficulty index, discrimination index, and distractor analysis. The reliability coefficient of the learning outcomes test was 0.78 (high category).

### Data Analysis

Normalized gain (N-gain) was calculated for each student. Prerequisite tests of normality (Kolmogorov Smirnov) and homogeneity of variance (Levene's test) were performed at $\alpha = 0.05$. Hypothesis testing was conducted using General Linear Model (GLM) Univariate and two-way ANOVA with SPSS 25. The decision criteria were based on the comparison of Fcalculated with Ftable (= 3.16) and the significance value ($p < 0.05$).

## RESULT AND DISCUSSION

### *Descriptive Statistics*

The descriptive statistics of pretest, posttest, and N-gain scores are presented in Table 1. Experimental Class 1 (Guided Inquiry eXe Learning) obtained a higher mean N-gain (0.835) than Experimental Class 2 (Direct Instruction eXe Learning) which obtained a mean N-gain of 0.681.

The distribution of critical thinking levels showed that Experimental Class 1 had 21 students (70%) in the high category and 9 students (30%) in the low category, while Experimental Class 2 had 19 students (63.3%) in the high category and 11 students (36.7%) in the low category.

### *Prerequisite Tests*

Kolmogorov Smirnov normality tests yield ed significance values greater than 0.05 for pretest, posttest, and N-gain data in both classes, indicating that the data were normally distributed. Levene's test for homogeneity of variance also produced significance values greater than 0.05 (pretest $p = 0.529$; posttest $p = 0.859$; critical thinking $p = 0.289$), confirming that the variances were homogeneous.

### *Hypothesis Testing*

The results of the two-way ANOVA are summarized in Table 2. The results indicate that: (1) students taught with Guided Inquiry eXe Learning achieved significantly higher learning outcomes than those taught with Direct Instruction eXe Learning ($F = 4.378 > 3.16$; $p = 0.041$); (2) students with high critical thinking skills obtained significantly higher learning outcomes than those with low critical thinking skills ($F = 4.642 > 3.16$; $p = 0.036$); and (3) there was a significant interaction between learning model and critical thinking level ($F = 6.470$; $p < 0.05$).

Further inspection of cell means revealed that the superiority of Guided Inquiry eXe Learning was most pronounced among students with high critical thinking skills (mean N-gain = 0.906), whereas for students with low critical thinking skills the two models produced relatively similar gains. This pattern suggests that the open-ended, exploratory nature of guided inquiry benefits students who already possess stronger analytical abilities, while Direct Instruction may provide more structured support for students with lower critical thinking skills.

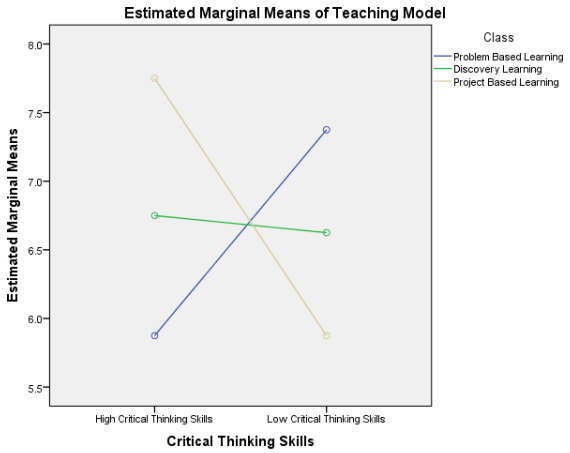
### *Discussion*

The higher effectiveness of Guided Inquiry assisted by eXe Learning is consistent with previous findings that inquiry-based approaches improve conceptual understanding and learning outcomes on buffer solution material (Saraswaty et al., 2019; Ilahi et al., 2023; Putri et al., 2025). The interactive features of eXe Learning such as self-check quizzes, hyperlinks, and visual representations support the inquiry stages by allowing students to explore content, test hypotheses, and receive immediate feedback.

The significant main effect of critical thinking level confirms that students with higher critical thinking skills are better able to process complex information and apply it to quantitative and qualitative problems related to buffer systems. The significant interaction effect indicates that the advantage of guided inquiry is moderated by students' critical thinking ability. Teachers should therefore consider students' critical thinking profiles when selecting instructional models and provide additional scaffolding for students with lower critical thinking skills.

These findings contribute to the literature by demonstrating that the combination of guided inquiry and eXe Learning produces not only higher average learning outcomes but also a differential effect depending on students' critical thinking level an aspect that has rarely been examined in previous studies on buffer solution learning.

| | | | |
|---|---|---|---|
| Pretest | Exp. 1 | Mean | N |
| | | 30 | |
| Pretest | Exp. 2 | 47.33 | 30 |
| N-Gain | Exp. 1 | 0.835 | 30 |




## CONCLUSION

Based on the results of the two-way ANOVA, it can be concluded that: (1) the Guided Inquiry learning model assisted by eXe Learning produces significantly higher chemistry learning outcomes on buffer solution material than the Direct Instruction model assisted by eXe Learning; (2) students with high critical thinking skills achieve significantly higher learning outcomes than students with low critical thinking skills; and (3) there is a significant interaction between learning model and critical thinking level in influencing learning outcomes. The Guided Inquiry eXe Learning combination is particularly beneficial for students with high critical thinking skills. These findings imply that chemistry teachers should consider integrating guided inquiry with interactive digital media and differentiate instructional support according to students' critical thinking profiles.

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