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The Effect of Applying Scaffolding Guidance on Students' Observing Skills in Deep Learning of Stoichiometry

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Abstract
This study aims to analyze the effect of applying scaffolding guidance on students' observing skills in the deep learning of stoichiometry. Observing is the most fundamental science process skill (SPS) and serves as the foundation for all other SPS aspects in building a deep understanding of chemistry concepts. This study employed a mixed methods approach using a concurrent triangulation design combined with a quasi-experimental time-series design without a comparison group. The sample consisted of 29 students from class X E8 at SMA Negeri 13 Jambi City, who took part in four meetings in which scaffolding guidance techniques were applied progressively: explaining (M1), prompting (M2), cueing (M3), and questioning (M4). The research instruments consisted of an SPS observation instrument and an essay pretest–posttest. Data were analyzed using the Shapiro Wilk normality test, the Friedman test, and the Wilcoxon signed rank test. The results showed that students' highest mean observing score was achieved at the second meeting (M2) using the prompting technique, at 2.92 (proficient), followed by M1 at 2.48 (proficient), M3 at 2.29 (proficient), and M4 at 1.00 (not proficient). The Friedman test indicated a significant effect of the four scaffolding techniques on the observing aspect (Asymp. Sig. < 0.05). The Wilcoxon signed-rank test on the essay results likewise revealed significant differences between most pairs of meetings. It can therefore be concluded that observing skills are highly dependent on the availability of structured observation guidance, and that the prompting technique delivered through worksheets (LKPD) proved the most effective in helping students systematically identify the physical characteristics of objects, compared with the other three scaffolding techniques.
Keywords: Scaffolding, Science Process Skills, Observing, Guided Inquiry, Stoichiometry

INTRODUCTION

Education is the process through which every individual pursues higher knowledge and understanding of specific objects or subjects (Paul et al., 2022). Under Indonesia's National Education System Law No. 20 of 2003, national education is intended to develop capabilities and shape the character and civilization of a dignified nation in order to advance the intellectual life of the nation, aiming to develop students' potential so that they become faithful, devout, virtuous, healthy, knowledgeable, capable, creative, independent, democratic, and responsible citizens (Silalahi et al., 2021). Science process skills (SPS) constitute a fundamental competency that every student must possess in chemistry learning. SPS refers to students' ability to apply the scientific method to understand, develop, and discover scientific knowledge (Fitriani et al., 2021). This competency encompasses an interrelated set of scientific skills, including observing, measuring, classifying, interpreting data, predicting, and communicating, which together form a coherent scientific understanding. International surveys indicate that Indonesian students' SPS remain relatively low. The 2015 Trends in International Mathematics and Science Study (TIMSS) ranked Indonesia 44th out of 49 countries, with a science score of

397 against an international average of 500 (Hadi & Novaliyosi, 2019). More recent data from the 2022 Programme for International Student Assessment (PISA) likewise show that the average science score of Indonesian students reached only 398, compared with an OECD average of 489 (OECD, 2023). This condition indicates the need for innovative learning strategies capable of systematically improving students' SPS.

Among the various aspects of SPS, observing is the most basic skill and underlies all other SPS aspects. Observing is the ability to use one or more senses carefully to identify and describe the physical properties of an object or phenomenon (Rustaman, 2011). In the context of chemistry, particularly in the abstract topic of stoichiometry, the ability to observe chemical-reaction phenomena is an essential prerequisite for building deep conceptual understanding. Preliminary observation at SMA Negeri 13 Jambi City revealed that students had never conducted laboratory practicums and that the learning process had not yet made optimal use of approaches that enhance SPS. This condition contributed to students' generally low SPS, including in the observing aspect, where students experienced difficulty systematically identifying and recording the physical characteristics of objects. One instructional approach shown to improve SPS is scaffolding guidance within a guided-inquiry model. Scaffolding is a form of temporary, graduated support provided by the teacher to help students complete tasks that lie beyond their actual capability but within their zone of proximal development (ZPD) (Vygotsky, 1978). Scaffolding techniques applied progressively from explaining (direct explanation), to prompting (reading materials/worksheets), to cueing (structured hints), and finally questioning (probing questions) enable students to gradually develop independence in scientific thinking (Anghileri, 2006).

Prior research by Ningrum et al. (2021) found that scaffolding-based worksheets containing structured observation guidance significantly improved students' observing skills in guided inquiry learning. Nevertheless, few studies have specifically examined the effect of each individual scaffolding technique on the observing aspect within a single longitudinal research design. Building on this background, the present study aims to analyze, both descriptively and statistically, the effect of applying four scaffolding guidance techniques on tenth grade students' observing skills in deep learning of stoichiometry at SMA Negeri 13 Jambi City. The focus on observing was chosen because this skill forms the foundation that determines the quality of all subsequent stages of scientific inquiry.

RESEARCH METHOD

This study was conducted in class X E8 at SMA Negeri 13 Jambi City, located on Jl. Sersan Udara Syawal, RT.03, Talang Bakung, Paal Merah, Jambi City, during the even semester of the 2025/2026 academic year. The research subjects were 29 students of class X E8, selected purposively based on field conditions. The study used a mixed methods design with a concurrent triangulation approach (Creswell, 2012), combining qualitative data from lesson implementation observation sheets and interviews with quantitative data from SPS observation sheets and essay tests. The quantitative component used a quasi experimental time series design, in which a single sample group took part in four consecutive meetings, each employing a different scaffolding guidance technique. The research procedure comprised four meetings, each applying a different scaffolding technique: Meeting 1 (M1) applied the explaining technique through direct explanation and demonstration by the teacher; Meeting 2 (M2) applied the prompting technique through a structured worksheet (LKPD) containing a systematic observation table; Meeting 3 (M3) applied the cueing technique through procedural hints in a practicum guide; and Meeting 4 (M4) applied the questioning technique through probing questions from the teacher without any written guidance. The intensity of guidance provided was progressively reduced from M1 to M4, in line with the fading principle of ZPD based scaffolding. The research instruments comprised: (1) an SPS observation rubric with an observing indicator namely, students' ability to determine the correct physical characteristics of the observed object scored on a 0–3 scale; (2) a lesson-implementation observation sheet; and (3) an essay pretest–posttest to measure cognitive SPS ability. SPS observation data were analyzed descriptively using the following criteria: 2.5–3.0 = highly proficient; 2.0–2.49 = proficient; 1.5–1.99 = approaching proficient; 1.0–1.49 = less proficient; and 0–0.99 = not proficient. Statistical analysis used the Friedman test to examine differences among the four scaffolding techniques and the Wilcoxon signed-rank test for pairwise comparisons between meetings.

RESEARCH RESULTS AND DISCUSSION

Descriptive Data on the Observing Aspect

Observation of lesson implementation at each meeting showed that all stages of the guided inquiry model were carried out in accordance with the lesson plan (RPP) across all four meetings. Specifically, at the data collection stage the stage at which the observing aspect was directly assessed by the observer field notes indicated differing patterns of student engagement at each meeting, corresponding to the change in scaffolding technique applied, as presented in Table 1.

Table 1. Results of Lesson-Implementation Observation at the Data-Collection Stage (Observing Aspect)

Meeting/Technique	Lesson-Implementation Observation Results (Data-Collection Stage)
M1 / Explaining	Some students carried out the experiment carefully and skillfully, while others were still not careful enough in observing, measuring, and recording data.
M2 / Prompting	Most students carried out the experiment carefully and were highly skilled at observing; a few students were still not careful enough in measuring.
M3 / Cueing	Most students carried out the experiment carefully and skillfully, although some were still not careful enough in observing, measuring, and recording observation data.
M4 / Questioning	Most students carried out the experiment carelessly and unskillfully in observing and recording observation data, although some students were skillful at measuring when guided by probing questions (questioning).

Based on Table 1, student engagement in observing at the data collection stage followed a non linear pattern as the intensity of scaffolding guidance decreased. At the first (M1) and third (M3) meetings, using the explaining and cueing techniques respectively, some students remained insufficiently careful in observing and recording data. At the second meeting (M2), using the prompting technique, students displayed the strongest observational accuracy, supported by a structured worksheet that guided the data collection process. Conversely, at the fourth meeting (M4), using the questioning technique with no written guidance, most students showed a decline in the accuracy of their observation and recording. These qualitative findings are consistent with the quantitative descriptive data presented in Table 2. Based on the science-process-skills observation data collected over the four meetings, the descriptive data for the observing aspect at each meeting are presented below.

Table 2. Descriptive Data for the Observing Aspect

SPS Aspect	Indicator	Meeting	Mean	Category
Observing	Students determine the correct physical characteristics of the observed object	M1	2.48	Proficient
		M2	2.92	Proficient
		M3	2.29	Proficient
		M4	1.00	Not Proficient

Based on Table 2, the highest mean score for the observing aspect was obtained at Meeting 2 (M2), at 2.92 (proficient), when the prompting scaffolding technique was applied through the structured worksheet. The second highest score occurred at Meeting 1 (M1), at 2.48, using the explaining technique, followed by Meeting 3 (M3) at 2.29 (proficient) using the cueing technique. The lowest score occurred dramatically at Meeting 4 (M4), at 1.00 (not proficient), where every student received the same score because no written guidance was available during the practicum using the questioning technique.

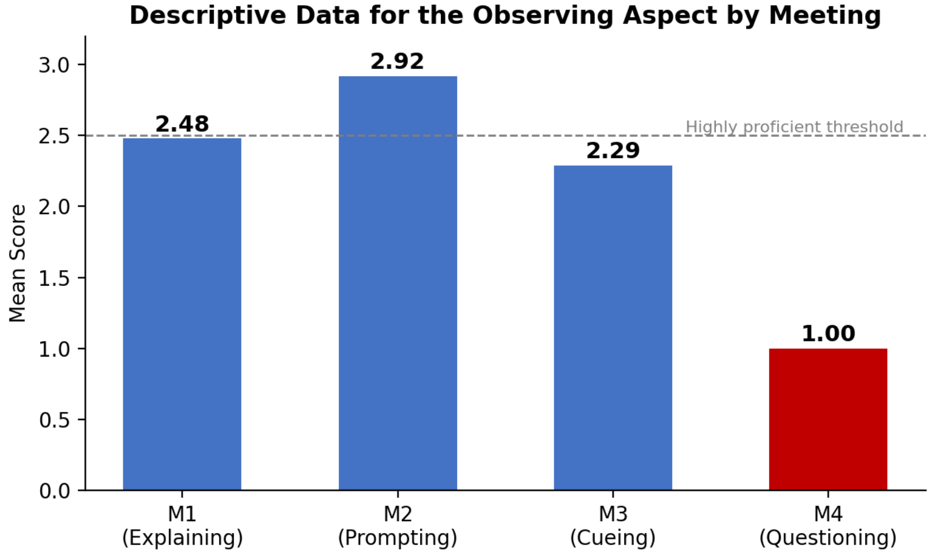

Figure 1. Chart of Descriptive Data for the Observing Aspect by Meeting

Normality and Homogeneity Tests for the Observation Data

Prior to further statistical testing, prerequisite normality and homogeneity tests were conducted on the observation data for the observing aspect across the four meetings. The Shapiro Wilk test was used for normality, and Levene's test was used for homogeneity, both at a 5% significance level (α = 0.05), as presented in Tables 3 and 4.

Table 3. Normality Test Results for the Observing-Aspect Observation Data

Meeting	Statistic	df	Sig.
M1	0.460	29	0.000
M2	0.742	29	0.000
M3	0.533	29	0.000
M4	Constant	–	–

Based on Table 3, the Shapiro–Wilk test results show a significance value of 0.000 (< 0.05) at Meetings 1, 2, and 3, while the data from Meeting 4 were constant because all students obtained the same score, making statistical testing inapplicable. The observation data for the observing aspect at all four meetings are therefore considered not normally distributed.

Table 4. Homogeneity Test Results for the Observing-Aspect Observation Data

Data	Levene Statistic	df1	df2	Sig.
Combined Observing Aspect, Meetings 1, 2, 3, and 4	19.569	3	112	0.000

The Levene's test result in Table 4 shows a significance value of 0.000 (< 0.05), indicating that the variance of the observation data for the observing aspect across the four meetings is not homogeneous. Because the data satisfy neither the normality nor the homogeneity assumption, further statistical analysis employed non-parametric approaches, namely the Friedman test and the Wilcoxon signed-rank test.

Friedman Test Results

The Friedman test was conducted to determine whether a significant difference existed among the four scaffolding guidance techniques with respect to the observing aspect. The results showed an Asymp. Sig. value of < 0.05 for the observing aspect, so H_0 was rejected, indicating a significant effect of applying the four scaffolding guidance techniques on students' observing skills.

Essay Test (Pretest–Posttest) Results for the Observing Aspect

In addition to the observation data, students' observing skills were also measured cognitively through essay pretests and posttests at each meeting. The pretest was administered at the beginning of Meeting 1, prior to the application of scaffolding guidance, while posttests were administered at the end of each meeting. The essay test results for the observing aspect are presented in Table 5.

Table 5. Essay Test (Pretest–Posttest) Results for the Observing Aspect

Essay Test	Mean	Category
Pretest M1	2.00	Proficient
Posttest M1	1.82	Approaching Proficient
Posttest M2	1.56	Approaching Proficient
Posttest M3	2.21	Proficient
Posttest M4	2.48	Proficient

Based on Table 5, the pretest mean score for the observing aspect was 2.00, which then decreased to 1.82 at Posttest M1 and 1.56 at Posttest M2, before rising again to 2.21 at Posttest M3 and reaching a peak of 2.48 at Posttest M4. This pattern indicates that students' cognitive observing ability on the essay test did not always align with their practicum observation performance: the best essay performance was achieved at Meeting 4 (questioning technique), in contrast to the observation data, which showed the best performance at Meeting 2 (prompting technique).

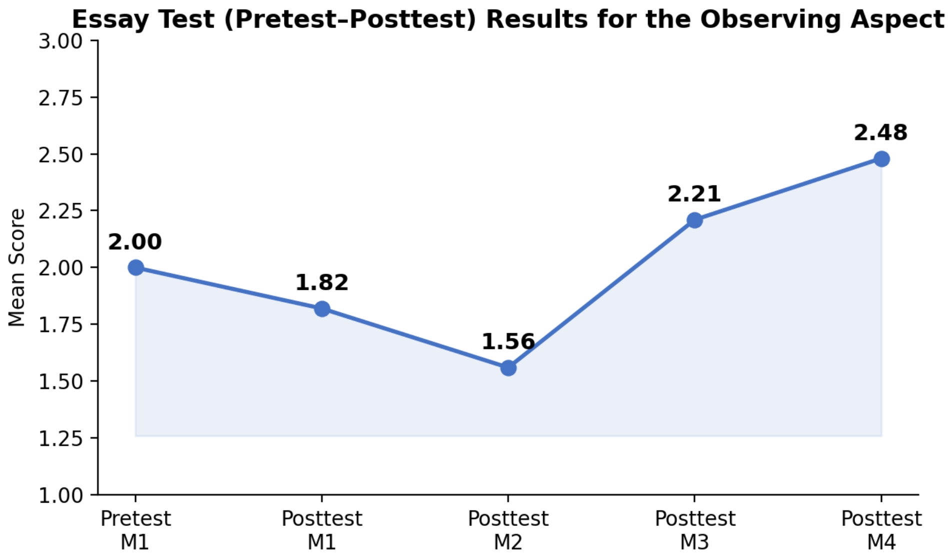

Figure 2. Chart of Essay Test (Pretest–Posttest) Results for the Observing Aspect

Normality and Homogeneity Tests for the Essay Test Data

As with the observation data, the essay test data for the observing aspect were also subjected to prerequisite testing prior to hypothesis testing. The normality and homogeneity test results for the essay test data are presented in Tables 6 and 7.

Table 6. Normality Test Results for the Essay Test Data on the Observing Aspect

Data	Statistic	df	Sig.
Pretest M1	0.617	29	0.000
Posttest M1	0.638	29	0.000
Posttest M2	0.602	29	0.000
Posttest M3	0.561	29	0.000
Posttest M4	0.460	29	0.000

The Shapiro–Wilk test results in Table 6 show a significance value of 0.000 (< 0.05) for all pretest and posttest data on the observing aspect, indicating that the essay test data are not normally distributed.

Table 7. Homogeneity Test Results for the Essay Test Data on the Observing Aspect

Data	Levene Statistic	df1	df2	Sig.
Combined Observing Aspect, Pretest–Posttest 1, 2, 3, and 4	4.442	4	140	0.002

The Levene's test result in Table 7 shows a significance value of 0.002 (< 0.05), indicating that the variance of the essay test data for the observing aspect across meetings is also not homogeneous. As the data satisfy neither the normality nor the homogeneity assumption, hypothesis testing was carried out using the non-parametric Wilcoxon signed-rank test, as presented below.

Wilcoxon Signed-Rank Test Results

To examine pairwise differences between meetings, the Wilcoxon signed-rank test was applied. The results showed: (1) the comparison between the Pretest M1 and Posttest M1 scores revealed a significant difference (H_0 rejected), with the mean score descriptively decreasing; (2) the comparison between Posttest M1 and Posttest M2 showed no significant difference (H_0 accepted), indicating that the explaining and prompting techniques had an equivalent effect on observing ability; (3) the comparison between Posttest M2 and Posttest M3 showed a significant difference (H_0 rejected), with the mean score increasing; and (4) the comparison between Posttest M3 and Posttest M4 showed a significant difference (H_0 rejected), with the mean score likewise increasing.

Discussion

The results reveal an intriguing pattern in the observing aspect, in which this skill did not follow a consistent trend as the intensity of guidance decreased. Instead, the peak in observing skill occurred with the prompting technique (M2) rather than with the explaining technique (M1), which provided the highest level of guidance intensity. This can be explained by a distinctive characteristic of the observing skill: its strong dependence on the availability of a structured observation-guidance instrument. At Meeting 1, using the explaining technique, although the teacher provided direct explanation and demonstration, students who were undertaking a chemistry practicum for the first time required an adjustment period before they could make full use of the available observation guidance. This produced a score of 2.48, within the proficient category but not yet optimal. At Meeting 2, using the prompting technique, the worksheet containing a structured observation table proved highly effective in helping students identify and record the physical characteristics of the objects observed. Students no longer relied on the teacher's verbal explanation but were instead guided by clear, measurable observation columns in the worksheet, yielding the highest score of 2.92. This finding is consistent with the study by Ningrum et al. (2021), which found that scaffolding based worksheets containing structured observation guidance significantly improved students' observing skills in guided-inquiry learning. Within Vygotsky's ZPD framework, the structured worksheet functions as a cognitive artifact that bridges students' actual ability with the potential ability they aim to achieve.

At Meeting 3, using the cueing technique, the practicum guide provided more general hints than the worksheet used at M2. Students were required to be more independent in selecting and recording the physical characteristics relevant to the task, without the benefit of specific observation columns. This produced a slight decrease in score to 2.29, still within the proficient category. This decline suggests that when observation guidance becomes more general, some students struggle to determine which physical aspects should be prioritized for observation. The most drastic decline occurred at Meeting 4 (M4), with a score of 1.00 (not proficient), where all 29 students obtained the same score. In the questioning technique, no written guidance whatsoever was available during the practicum, and the teacher provided only probing questions. This condition reveals a fundamental limitation in the observing aspect: without a concrete guidance instrument, students struggled to maintain observational sharpness independently. Overall, these findings confirm that the observing aspect is highly dependent on the availability of a structured observation guidance instrument. The most effective scaffolding technique for this aspect is prompting through a structured worksheet, whereas the questioning technique without written guidance posed the greatest challenge for students. These findings carry practical implications for chemistry teachers: developing worksheets with systematic observation tables is a highly important pedagogical investment for building students' observing skills, particularly in the early stages of inquiry-based learning.

Beyond the practicum observation data, the essay pretest–posttest results provide a complementary picture of students' observing skills, particularly from the standpoint of their cognitive ability to express observation results in writing. Notably, the pattern found in the essay test did not entirely align with the pattern found in the practicum observation data. The pretest mean of 2.00 (proficient), obtained prior to the scaffolding intervention, decreased to 1.82 at Posttest M1 and 1.56 at Posttest M2, even though the practicum observation data showed that M2 was in fact the meeting with the highest achievement in observing skill. This divergence suggests that psychomotor observing ability during the practicum does not necessarily correspond directly with students' cognitive ability to articulate observation results in written form. The structured worksheet used in the prompting technique was highly effective in guiding students to record the physical characteristics of objects systematically during the practicum, but the observation columns it provided did not necessarily train students to organize and communicate those results independently, in essay form, without a similar structural aid. This is consistent with the view of Rahmawati (2023), who argues that science process skills encompass both psychomotor and cognitive dimensions that do not always develop in parallel, since each demands a different mode of thinking: the psychomotor dimension emphasizes the precision of direct action, whereas the cognitive dimension demands the ability to organize and communicate understanding in structured written form.

The essay-score pattern then reversed, rising to 2.21 at Posttest M3 and reaching its highest value of 2.48 at Posttest M4 coinciding with the meetings that involved the lowest intensity of guidance. The Wilcoxon signed-rank test showed that the increases between both of these pairs of meetings (Posttest M2 to Posttest M3, and Posttest M3 to Posttest M4) were statistically significant. This finding suggests that the reduction in written guidance under the cueing and questioning techniques encouraged students to think more independently and actively when composing their essay answers, since they were no longer able to rely on the standardized observation-column format used in the M2 worksheet. This increase may also reflect a learning-curve effect, whereby students became increasingly accustomed to the format of the SPS essay questions after repeated exposure across meetings, thereby sharpening their ability to organize written answers over time. The absence of a significant difference between Posttest M1 and Posttest M2 (H_0 accepted) further supports this interpretation, indicating that the explaining and prompting techniques produced a relatively comparable cognitive effect during the early stage of learning, before students' independent thinking developed more markedly in later meetings.

This divergence between the observation data and the essay test data enriches the interpretation of observing as a component of science process skills. The observation data confirm that the availability of structured guidance, such as a worksheet, strongly determines the sharpness and accuracy of students' direct observation during the practicum. The essay data, by contrast, show that students' cognitive ability to describe and analyze observation results in writing is in fact better honed when students are required to think and formulate answers more independently, as occurred under the cueing and questioning techniques. Observing skill can therefore be understood as multidimensional: a field-practice dimension that requires explicit, structured guidance, and a cognitive-written dimension that develops optimally through the gradual reduction of assistance, consistent with the fading principle of ZPD based scaffolding. The implication is that chemistry teachers need to design a combination of scaffolding strategies that does not focus on a single form of assessment alone, but instead integrates structured written guidance to support the sharpness of practical observation while also providing space for independent thinking, through reflective questioning, to train students' cognitive ability to communicate their observation results in writing.

CONCLUSION

The progressive application of scaffolding guidance had a significant effect on the observing skills of class X E8 students at SMA Negeri 13 Jambi City in the deep learning of stoichiometry, as shown by both the practicum observation data and the cognitive essay test data. The Friedman test on the observation data showed a significant effect of the four scaffolding guidance techniques (Asymp. Sig. < 0.05), with the prompting technique delivered through a structured worksheet proving the most effective in improving students' practical observing skills, yielding the highest mean score, whereas the questioning technique without written guidance resulted in a drastic decline in observing skill to the not-proficient level. Conversely, the Wilcoxon signed-rank test on the essay test data revealed a different pattern, in which students' cognitive observing ability declined at Posttest M1 and M2 before increasing significantly at Posttest M3 and reaching its highest value (proficient) at Posttest M4, under the questioning technique. This divergence confirms that observing skill is multidimensional, comprising a psychomotor-practical dimension that develops optimally with structured observation guidance, and a cognitive-written dimension that develops optimally when students are trained to think independently through the gradual reduction of assistance. These findings recommend that chemistry teachers not only prioritize the development of worksheets with systematic observation tables as a foundation for practical observing skill, but also consistently train students to formulate their observation results in written form through reflective questioning, so that both dimensions of observing skill psychomotor and cognitive can develop in a balanced manner. For future research, it is recommended that the effectiveness of scaffolding on the observing aspect be examined using visual media or augmented reality as a substitute for written guidance in conditions without a worksheet, and that further research investigate the factors underlying the divergent patterns between students' psychomotor and cognitive observing abilities.

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