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The Feasibility of Student Worksheets Based on Analytical Thinking Skills with Guided Inquiry on Chemical Equilibrium Material Containing Three Scientific Questions

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Abstract

This study aims to develop a student worksheet based on analytical thinking skills using a guided inquiry model that includes three scientific questions on the factors affecting shifts in chemical equilibrium. The study employed a research and development method using the ADDIE model, limited to the development stage, followed by a pilot implementation. The research subjects consisted of three validators and 32 11th-grade students at SMA Hang Tuah 5 Sidoarjo. Product validity was analyzed using Aiken's V index; practicality was assessed based on student response questionnaires and observations of the implementation of learning activities; and changes in analytical thinking skills were analyzed using the Wilcoxon Signed-Rank test. The results showed that all three student worksheet met the criteria for high validity in terms of content and construct. Student responses achieved an average percentage of 92.75%, while the implementation of learning activities reached 94%. Preliminary test results showed an increase in the percentage scores for the indicators of distinguishing (50.26% to 94.27%), organizing (39.45% to 83.98%), and connecting (30.99% to 80.99%). The increase in pretest and posttest scores was statistically significant ($p < 0.001$), with an effect size of $r = 0.87$. These findings provide preliminary evidence of an increase in analytical thinking scores following the use of student worksheet.

Keywords: Analytical Thinking Skills; Student Worksheet; Guided Inquiry; Chemical Equilibrium; Three Scientific Questions.

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1. Introduction

Advances in science and technology require students to possess the thinking skills necessary to face various challenges. Therefore, learning should not only focus on mastering concepts but also on developing higher-order thinking skills (Miterianifa et al., 2021). One of the key skills in chemistry learning is analytical thinking skill (ATS) the ability to distinguish, organize, and connect information to understand a problem (Anderson & Krathwohl, 2001). This skill is essential for studying chemical equilibrium, as students must analyze the relationship between changes in a system's conditions and the direction of the equilibrium shift. This aligns with the Phase F Chemistry Learning Outcomes, which require students to analyze the concept of chemical equilibrium and its applications in daily life (BSKAP, 2025). Thus, instruction on chemical equilibrium must be designed to facilitate conceptual mastery while simultaneously developing students' analytical thinking skills.

Although analytical thinking skills (ATS) are important in learning about chemical equilibrium, research by Damayanti and Novita (2024) shows that students' achievement on the indicators of distinguishing, organizing, and connecting was only 60%, 42%, and 39%, respectively. These findings indicate that students still face difficulties in distinguishing the effects of each factor on equilibrium shifts, organizing information regarding relationships between concepts, and connecting changes in system conditions with the direction of equilibrium shifts based on Le Chatelier's principle. These difficulties are related to the nature of chemical equilibrium material, which requires conceptual understanding and analysis of relationships between variables, while teaching that tends to be teacher-centered focused on the transmission of information can limit students' opportunities to construct knowledge through the process of inquiry (Indriani et al., 2017; Maulidiya & Novita, 2024). Therefore, instructional materials are needed that not only present concepts but also provide students with opportunities to investigate phenomena and practice analytical thinking skills in a guided manner.

The development of instructional materials focused on analytical thinking skills must be supported by a learning model that provides students with opportunities to build understanding through the process of inquiry. The guided inquiry model can be used to guide students in formulating problems, developing hypotheses, conducting investigations, analyzing data, and drawing conclusions (Arends, 2012). In this research, the stages of guided inquiry were integrated with three scientific questions ontology, epistemology, and axiology which relate, respectively, to what is being studied, how knowledge is acquired, and the benefits of knowledge (Suriasumantri, 2017).

This integration is reflected in student worksheet activities that guide students to distinguish between correct and incorrect definitions of the factors influencing shifts in chemical equilibrium through ontology questions. Furthermore, epistemology questions guide students in formulating variables and hypotheses, conducting investigations, organizing observational data, and explaining the relationship between changes in system conditions and the direction of equilibrium shifts based

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on Le Chatelier's principle. Axiology questions guide students to relate the concepts they have learned to their applications through the phenomena of photosynthesis, the Haber–Bosch process, and carbonated beverages. This series of activities is designed to develop three indicators of analytical thinking skills: distinguishing information or concepts, systematically organizing observational results, and connecting investigation results to the concept of chemical equilibrium and its applications (Anderson & Krathwohl, 2001). Thus, the three scientific questions are not merely added to the inquiry stages but are used to guide students' thinking processes throughout each series of learning activities.

Several studies have developed guided inquiry-based instructional materials to support chemistry learning(Awwaludin & Novita, 2024; Satura et al., 2021). Rahmawati and Suyono (2022) examined the use of three scientific questions ontology, epistemology, and axiology in chemistry instruction on the topic of factors affecting reaction rates. This research provides a relevant foundation for the development of instructional materials that integrate these three scientific questions. However, the development of student worksheet that combine these three scientific questions with the guided inquiry model and indicators of analytical thinking skills regarding the factors influencing shifts in chemical equilibrium still requires further study. Therefore, this research developed three student worksheets addressing the factors of concentration, temperature, and pressure and volume. The novelty of this research lies in the integration of the three scientific questions into the guided inquiry stages to facilitate the practice of the three indicators of analytical thinking skills when studying the factors influencing the shift in chemical equilibrium. The quality of the resulting products was then assessed based on validity, practicality, and effectiveness through a pilot implementation.

This research aims to develop a student worksheet based on analytical thinking skills using a guided inquiry model that includes three scientific questions on the topic of chemical equilibrium shifts, covering the factors of concentration, temperature, and pressure and volume. The feasibility of the student worksheet was assessed based on content and construct validity, its practicality was evaluated based on student responses and observations of the implementation of learning activities, and its effectiveness was determined based on improvements in analytical thinking scores before and after the use of the student worksheet during the pilot implementation.

2. Methods

This is a research and development project that employs the ADDIE model (Analyze, Design, Develop, Implement, and Evaluate), limited to the Develop stage, followed by a pilot implementation to assess the product's feasibility based on validity, practicality, and effectiveness. The developed product consists of three student worksheet that cover the factors of concentration, temperature, and pressure and volume.

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During the Analyze phase, learning needs were analyzed through a literature review and curriculum analysis to identify the characteristics and scope of the chemical equilibrium material, its relationship to analytical thinking skill indicators, and the need to integrate the three scientific questions. The results of the analysis were used as the basis for designing products in the Design phase, which included developing the structure of the student worksheet, learning activities based on the guided inquiry syntax, and research instruments. In the Develop stage, the design was implemented into three student worksheet that included contextual phenomena, investigative problems, hypothesis formulation, data collection and analysis, formulation of explanations based on investigation results, and reflection on the concepts studied, these were then validated by three validators, two chemistry education lecturers and one chemistry teacher. The student worksheet was revised based on the validators suggestions and feedback before being used in the pilot implementation. The pilot implementation was conducted with 32 students in Class 11-3 at SMA Hang Tuah 5 Sidoarjo.

The student worksheet was validated to assess its validity. Validity data were obtained through validators' assessments of content validity and construct validity. The validation assessment used the Likert scale shown in Table 1.

Table 1.
Likert Scale for Validity

Category	Score
Very invalid	1
Invalid	2
Partially valid	3
Valid	4
Very valid	5

(Riduwan, 2023)

Validity data were analyzed using Aiken's V (1985) formula, as follows.

$$V = \frac{\sum s}{(n\ x\ (c-1))}$$

Description:
V = student worksheet validity
s = the score given by the evaluator minus the lowest validation score
n = number of validators
c = highest validity score

Aiken's standard validity scores are then categorized as shown in the following Table 2.

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Table 2.
Aiken's V Validity Scales Category

Score	Category
$0 < V \leq 0,4$	Invalid
$0,4 < V \leq 0,8$	Valid
$0,8 < V < 1$	Very valid

(Retnawati, 2016)

Data on practically obtained through a student response questionnaire containing positive and negative statements and data on the monitoring of student activity implementation. The scores for the student response questionnaire were determined using the Guttman scale with "Yes" or "No" response options, as shown in Table 3.

Table 3.
Guttman Scale

Answer	Postive Statement Score	Negative Statement Score
Yes	1	0
No	0	1

(Riduwan, 2023)

Then, the data is converted into percentages using the following formula:

$$\frac{\Sigma \text{ Yes/No Answer}}{\Sigma \text{ Maximum Score}} \text{ x } 100\%$$

The data from observations of student activity participation were using a Likert scale, as presented in Table 4.

Table 4.
Score Scale

Assessment	Score
Did not perform	0
Did not fully perform	1
Perform	2

(Riduwan, 2023)

The data obtained was analyzed by presenting the results as percentages calculated using a formula.

$$\frac{\Sigma \text{ Score Obtained}}{\Sigma \text{ Maximum Score}} \text{ x } 100\%$$

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These percentage results were then used to determine the practicality of using the Likert scale, as shown in Table 5.

Table 5.
Likert Scale for Practicality

Achievement Level (%)	Category
0-20	Very unpractical
21-40	Unpractical
41-60	Partially practical
61-80	Practical
81-100	Very practical

(Riduwan, 2023)

The pretest and posttest results were analyzed using the Wilcoxon Signed-Rank test and the r effect size. The Wilcoxon Signed-Rank test was used to determine the improvement in students analytical thinking skills. The hypotheses used were as follows:

a. H_0: There is no increase in pretest and posttest scores after using student worksheet
b. H_a: There is an increase in pretest and posttest scores after using student worksheet

The basis for drawincog conclusions in this test is as follows.

a. If sig. < 0.01, then H_0 is rejected and Ha is accepted, meaning that there is an increase in the average pretest and posttest scores. This means that the developed student worksheet is considered effective.
b. If sig. > 0.01, then H_0 is accepted and Ha is rejected, which means there is no increase in the average pretest and posttest scores. This means that the developed student worksheet is considered ineffective.

The r effect size test was used to determine the impact of using student worksheets on improving ATS, which was calculated using the formula.

$$r = \frac{Z}{\sqrt{N}}$$

Description:
r = effect size
Z = score Z
N = sample amount

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The scores obtained were then converted into the categories shown in Table 6.

Table 6.
Score Effect Size

Effect Size	r
Very small	0,0 ≤ r ≤ 0,1
Small	0,1 ≤ r ≤ 0,3
Medium	0,3 ≤ r ≤ 0,5
Large	≥ 0,5

(Cohen, 1988)

3. Result and Discussion
3.1. Result
3.1.1. Analyze

The Analysis Stage is the first stage conducted to identify possible causes of gaps (Branch, 2009), during which a needs analysis and a curriculum analysis are carried out. Needs analysis is conducted through a review of previous research. Damayanti and Novita (2024) reported that students' analytical thinking skills, as measured by the indicators of distinguishing, organizing, and connecting, were 60%, 42%, and 39%, respectively. Meanwhile, Maulidiya (2024) reported percentages of 22.9% for the distinguishing indicator, 17.1% for the organizing indicator, and 53.3% for the connecting indicator. Furthermore, Indriani et al. (2017) identified students' difficulties in understanding the factors that influence shifts in chemical equilibrium, including concentration, temperature, pressure, and volume. Further literature reviews also indicate that instructional materials in the form of student worksheet that specifically integrate the guided inquiry model with three scientific questions are still not available (Rahmawati & Suyono, 2022).

The curriculum analysis was conducted by identifying the scope of the material based on the Phase F Chemistry Learning Outcomes in BSKAP Director's Decision No. 046/H/KR/2025. The developed content covers concentration, temperature, as well as pressure and volume. The results of the analysis served as the basis for developing the student worksheet, which links the content to indicators of analytical thinking skills, guided inquiry syntax, and three scientific questions: ontology, epistemology, and axiology. The evaluation was conducted in collaboration with the supervising instructor. The evaluation results indicate that the needs analysis was supported by a review of relevant research, while the content analysis was consistent with the Learning Outcomes and accommodated the guided inquiry model, indicators of analytical thinking skills, and the three scientific questions.

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3.1.2. Design

The design phase involved establishing the format and structure of the student worksheet using Canva and Microsoft Word. The design was based on the results of a needs analysis and material on chemical equilibrium, linked to indicators of analytical thinking skills, the syntax of the guided inquiry model, and three scientific questions: ontology, epistemology, and axiology. The designed products consist of three student worksheets, covering the factors of concentration, temperature, and pressure and volume. The structure of the student worksheet includes a cover page, preface, table of contents, general information, an explanation of the analytical thinking skill indicators, the guided inquiry syntax, an explanation of the three scientific questions, and learning activities.

At this stage, research instruments were also developed, including a validation sheet, a student response questionnaire, a classification sheet for written student worksheet documents, and analytical thinking ability tests in the form of pretests and posttests. The design phase evaluation was conducted together with the supervising instructor to review the alignment of the student worksheet design with the development objectives. The evaluation results were used as the basis for refining the design before proceeding to the development phase.

3.1.3. Develop

During the development phase, the student worksheet design was refined and validated by three validators, consisting of two chemistry education faculty members and one chemistry teacher. Validation was conducted on two aspects: content validity and construct validity. Content validity covers the accuracy of the material on chemical equilibrium, the alignment of activities with indicators of analytical thinking skills, the application of the guided inquiry model, and the inclusion of three scientific questions. Meanwhile, construct validity assesses the alignment of the student worksheet activity sequence with the stages of guided inquiry. Table 5 presents the overall validation results, calculated based on the average of all validation criteria.

Table 7.
Validity Result

Product	V Score	
	Content Validation	Construct Validation
Student Worksheet-1	0,972	0,944
Student Worksheet-2	0,926	0,931
Student Worksheet-3	0,880	0,917

Based on the validation results, the student worksheeet was revised in accordance with the validators feedback. The revisions included clarifying the color-coding for the analytical thinking indicator, refining the activities for the organizing indicator, improving examples of how concepts are applied in daily life, adding instructions prior to calculating equilibrium constants, and

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providing a clearer explanation of the equilibrium shift process. These improvements were made to clarify the activities and instructions so that they align with the learning objectives. After the revision process, the student worksheet was used in a pilot implementation with 11th-grade students in Phase F at SMA Hang Tuah 5 Sidoarjo.

3.1.4. Pilot Implementation

The pilot implementation phase aims to determine the feasibility of the student worksheet in terms of practicality and effectiveness. In this phase, the research instruments used include a student response questionnaire, an analytical thinking skills test, and a student activity implementation sheet, all of these instruments have been validated and suitable for use in this research.

The effectiveness of the student worksheet was assessed based on the increase in students' pretest and posttest scores on analytical thinking skills. Pilot implementation was conducted with 32 11th-grade students in Phase F at SMA Hang Tuah 5 Sidoarjo. The pretest and posttest results were analyzed based on three indicators of analytical thinking skills: distinguishing, organizing, and connecting. The percentage of scores for each indicator is presented in Table 8.

Table 8.
Percentage of Pretest and Posttest Results for Each ATS Indicator

No.	Analytical Thinking Skill Indicators	*Pretest* (%)	*Posttest* (%)
1.	Differentianting	50,26	94,27
2.	Organizing	39,45	83,98
3.	Connecting	30,99	80,99

Based on Table 8, the posttest scores were higher than the pretest scores for all three indicators of analytical thinking skills. The distinguishing indicator increased from 50.26% to 94.27%, while the organizing indicator increased from 39.45% to 83.98%. For the connecting indicator, the percentage of scores increased from 30.99% to 80.99%. The largest increase, based on the percentage difference, was observed in the connecting indicator, followed by the organizing and distinguishing indicators. All pretest and posttest scores were then analyzed using the Wilcoxon Signed-Rank Test via Minitab 22 software. The test results are presented in Table 9.

Table 9.
Results of the Wilcoxon Signed-Rank Test

Sample	N for Test	Wilcoxon Statistic	P-Value
DATA WILCOXON	32	0,00	0,000

The test results showed a statistic value of 0.00 and a p-value of < 0.001. These findings indicate an improvement in analytical thinking skills following the instruction; however, the single-group

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design without a control group does not allow this improvement to be fully attributed to the use of student worksheet. Furthermore, the effect size (r) was 0.87, which falls into the "large" category.

The practicality of student worksheet was assessed based on students' responses after participating in a lesson using student worksheet based on ATS, employing a guided inquiry model that included three scientific questions. Students' responses were collected through a questionnaire consisting of 15 statements. Details of the average student response scores are presented in Table 10.

Table 10.
Average Results of the Student Response Survey

Aspects	Average Percentage (%)	Category
To determine students' responses to instruction on analytical thinking skills in the topic of chemical equilibrium.	94	Very practical
To determine students' responses to the instructional stages implemented by the teacher.	90	Very practical
To determine students' responses to the strengths and weaknesses of the teacher's instruction.	91	Very practical
To determine students' evaluations of the use of student worksheet.	96	Very practical

Based on Table 10, the aspect of student responses to learning analytical thinking skills received a response rate of 94%, followed by the aspect of student responses to the stages of learning at 90%, the aspect of the strengths and weaknesses of the student worksheet at 91%, and the aspect of student evaluations of the use of the student worksheet at 96%. These results indicate that students responded positively to the use of the student worksheet. In addition to the student response questionnaire, the implementation of learning activities was observed during the use of the student worksheet. The observations were conducted with the assistance of 6 observers and covered 8 activities. The results of the observations for all student worksheet are presented in Table 11.

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Table 11.
Results of the Observation of the Implementation of Learning Activities

No.	Activity	Student Worksheet Percentage (%)			Avarage (%)
		1	2	3	
1.	Students read the provided narrative to understand Le Chatelier's principle (axiology).	100	100	90	97
2.	Students wrote down the results of distinguishing equilibrium concepts according to equilibrium factors based on the narrative presented in the student worksheet (ontology).	100	100	100	100
3.	Students wrote down the results of distinguishing experimental variables (epistemology).	90	90	80	87
4.	Students wrote down the results of organizing information to formulate a hypothesis (epistemology)	100	100	100	100
5.	Students conduct laboratory activities according to the instructions provided (epistemology).	90	90	100	93
6.	Students organize the experimental results in an observation table (epistemology).	100	100	80	93
7.	Students write answers to questions by relating the concept of chemical equilibrium including explanations of changes in the system and its connection to Le Chatelier's Principle (epistemology).	90	90	80	87
8.	Students write conclusions and relate the application of factors affecting shifts to everyday life (axiology).	90	90	100	93
Avarage					94

Based on Table 11, the activities of distinguishing equilibrium concepts based on narratives and organizing information to formulate hypotheses achieved a 100% implementation rate. Meanwhile, the activities of distinguishing experimental variables and relating changes in the system to Le Chatelier's principle achieved the lowest average, at 87%. Overall, the observation results show

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that the learning activities designed in the student worksheet were implemented with an average percentage of 94%.

3.2. Discussion
3.2.1. Validity

The validation results show that all three student worksheet meet the criteria for high validity in terms of content and construct. The Aiken's V values for content validity of student worksheet 1, student worksheet 2, and student worksheet 3 were 0.972, 0.926, and 0.880, respectively, while the construct validity values were 0.944, 0.931, and 0.917, respectively. These results indicate that the content, learning objectives, indicators of analytical thinking skills, and the sequence of activities in the student worksheet align with the assessed aspects. These findings are consistent with the research by Yanti et al. (2022), which emphasizes the importance of aligning learning components with the stages of the guided inquiry model in the development of valid worksheets. The similarity lies in the use of the guided inquiry stages as the basis for designing learning activities.

This research, while having similarities in the use of guided inquiry, introduces a novelty in the integration of three scientific questions ontology, epistemology, and axiology with indicators of analytical thinking skills regarding the factors that influence shifts in chemical equilibrium. Ontological questions are designed to help students distinguish between concepts; epistemological questions guide the process of inquiry and the organization of information; while axiological questions direct students to relate concepts to their applications in everyday life. This integration distinguishes the student worksheet developed from guided inquiry-based instructional materials that focus solely on the inquiry stages. Revisions based on validator feedback such as refinements to the information-organizing activity and the explanation of equilibrium shifts were also made to clarify the alignment of the activities with the development objectives. Thus, the validation results support the feasibility of the student worksheet based on content and construct aspects, with its novelty lying in the systematic integration of the three types of scientific questions and analytical thinking skills.

3.2.2. Effectiviness

The results of the pilot implementation showed that the percentage of scores for analytical thinking skills increased across all three indicators following instruction using student worksheet. The distinguishing indicator increased from 50.26% to 94.27%, organizing from 39.45% to 83.98%, and connecting from 30.99% to 80.99%. The largest increase, based on the percentage difference, occurred in the connecting indicator, amounting to 50.00 percentage points. The results of the Wilcoxon Signed-Rank test showed a p-value < 0.001, with an effect size of $r = 0.87$, which falls into the "large effect" category. These findings indicate a statistically significant increase in pretest and posttest scores, accompanied by a large effect size. These results are consistent with the studies by Damayanti and Novita (2024) and Maulidiya and Novita (2024), who developed student

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worksheet to support the learning of chemical equilibrium concepts. In the student worksheet developed in this research, the inquiry-based activities provided students with the opportunity to distinguish concepts, organize information from their observations, and relate changes in system conditions to Le Chatelier's principle.

The largest increase in the connecting indicator suggests that the most significant change in scores occurred in the ability to relate learned information and concepts. This may be related to the student worksheet activities, which guided students to analyze investigation results, explain shifts in equilibrium based on Le Chatelier's principle, and connect concepts to phenomena in everyday life. These characteristics constitute a novel aspect of this research, namely the integration of three scientific questions ontology, epistemology, and axiology with the stages of guided inquiry and indicators of analytical thinking skills. However, because the research used a single-group design without a control group, the increase in scores cannot yet be fully attributed to the use of the student worksheet. Thus, based on the increase in pretest and posttest scores, the results of the Wilcoxon test, and the effect size values, the developed student worksheet shows indications of effectiveness in supporting students' analytical thinking skills regarding chemical equilibrium material during the pilot implementation.

3.2.3. Practically

The practicality of student worksheet was assessed based on student responses and the implementation of learning activities during the pilot implementation. The survey results showed that student responses to the use of student worksheet had an average percentage of 92.75% and fell into the very practical category. These results indicate that students responded positively to the learning activities, the guided inquiry stages, and the use of student worksheet to develop analytical thinking skills.

Observations of the implementation of the eight learning activities showed an average implementation rate of 94%. The activities involving distinguishing the concept of equilibrium based on a narrative and organizing information to formulate a hypothesis achieved a 100% implementation rate, while the activities involving distinguishing experimental variables and relating changes in a system to Le Chatelier's principle had the lowest implementation rate, at 87%. These findings suggest that most of the activities designed in the student worksheet could be implemented during instruction, although some analytical activities still require attention. The integration of guided inquiry stages, three scientific questions, and indicators of analytical thinking skills are characteristic features of the developed student worksheet. Thus, student responses and the results of implementation observations collectively support the assessment that the student worksheet demonstrated good practicality during the pilot implementation.

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4. Conclusion

This research produced student worksheet based on analytical thinking skills using a guided inquiry model that included three scientific questions on the factors affecting shifts in chemical equilibrium, including concentration, temperature, and pressure and volume. The assessment results from three validators provide preliminary evidence of the product's content and construct validity. The practicality of the student worksheet is supported by positive student responses, with an average percentage of 92.75%, as well as a 94% implementation rate of learning activities. A pilot implementation involving 32 students from a single class at one school showed an increase in analytical thinking scores following the use of the student worksheet, with Wilcoxon test results indicating a statistically significant difference between pretest and posttest scores ($p < 0.001$) and an effect size of $r = 0.87$. However, these results do not yet prove that the increase in scores was entirely due to the use of the student worksheet. This research was limited to a single class, a single school, and a single pilot implementation, and did not include a control group. Therefore, further testing involving more classes, schools, and a control group is needed. The developed student worksheet has the potential to serve as an alternative teaching material for chemical equilibrium instruction and to support the development of students' analytical thinking skills.

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