## "Improving Stoichiometry Learning Outcomes through Discovery Learning with Scaffolding-Based Worksheets"

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## Abstract

This study provides a complete evaluation of the effectiveness of scaffolding-based Student Worksheets in teaching stoichiometry utilizing the discovery learning methodology. The study found that combining active learning strategies with structured worksheets improves students' learning outcomes, particularly in terms of engagement and knowledge acquisition. The high n-gain value of 0.72 emphasizes the positive impact of this approach, indicating that students taught using this method make significant progress. A key strength of the study is its quasi-experimental design, which allows for a thorough comparison of the traditional discovery learning model and the scaffolding-enhanced approach. The observation that students demonstrated "very good" engagement adds to the conclusion that scaffolding-based worksheets are extremely beneficial. Given the positive outcomes, the research suggests that educators should consider adopting this hybrid method to boost both student performance and participation. The recommendation for future studies to explore the long-term impact of this approach and its broader applicability is also essential, as it could lead to a deeper understanding of how these methods influence sustained learning. The learning computed effectiveness as measured by significant N-gain value of 0.72 reflects to high efficacy or underlying the what we call high category. These findings have potential implications for facilitators and curriculum designer. Educationist can utilize the discovery learning paradigm in conjunction with scaffolding-based Student Worksheets to increase student engagement and knowledge of stoichiometry. The demonstrated effectiveness of this methodology suggests that it could be implemented into chemistry education methodologies, resulting in improved learning results. Based on the results of the conduct study it is much better to used scaffolds in order to gain higher performances.

**Keywords**: *Learning Model, Scaffolding, Stoichiometric, Students Learning.*

## Introduction

Stoichiometry is an example of an abstract concept taught in chemistry (Sappaile, 2019). Abstract chemical information makes it harder for learners to understand the lesson, preventing them from learning actively. Learners typically learn by rote rather than actively trying to improve their comprehension of an idea. knowledge chemical topics requires a

Proper comprehensiom of the fundamental concepts that support them. As a result, meaningful learning settings are required for students to fully comprehend the idea of stoichiometry (Nahum, Hofstein, Mamlok-Naaman, and Ziva, 2004; Taber, 2000). According to the results of interviews with chemistry educators at Senior High School of Taganito Claver District on December 10, 2024, the 2013 curriculum was applied, and students' conceptual competence remains low. Learning outcomes (daily assessments) reflect this. According to the Chemistry educator who teaches in class, another challenge student has when studying stoichiometry subject is a lack of learning materials and learning media that can help them learn. Given this reality, learning media are required to increase and promote the quality of learning on stoichiometric content. Teachers play an extremely essential role in resolving this difficulty. One method that teachers might take to create an inventive.

The discovery learning approach is useful for chemical problem solving abilities. The guided discovery learning model has a significant impact on students' critical thinking skills in learning, encourages students to think creatively, and assists students in discovering new knowledge or concepts in chemistry; the learning environment is more enjoyable and challenging for students to discover their concepts (Kawuri and Fayanto, 2020; Nurfadilah, Maruto, & Fayanto, 2020; Sahara, Nafarudin, Fayanto, & Tairjanovna, 2020). Furthermore, students can practice science process skills (Yondriadi and Yerimadesi, 2019). Learning media, in addition to effective learning paradigms, are required for successful teaching and learning.

Learning media is a helpful tool in the learning process (Fayanto, Misrawati, Sulisworo, Istiqomah, & Sukariasih, 2019). A scaffolding-based Student Worksheet is one learning medium that can be adapted to students' ability levels. The combination of Student Worksheets with scaffolding, which inspire students to think with many instructions given and provides the necessary assistance on certain materials, will make it easier for students to understand the concept of the material being Students learn individually so that they can better understand the subject. The Student Worksheet projects facets of students' conceptual comprehension.

STATEMENT OF THE PROBLEM

🠶 This study was intended primarily to explore the effectiveness of the discovery learning model integrated with student

worksheets and scaffolding techniques in enhancing students’ understanding and mastery of stoichiometric materials.

Research Questions:

The specific research questions below guided the researcher in the direction of the study:

* How does the application of the discovery learning model with student worksheets based on scaffolding affects students’ comprehension of stoichiometric concepts?
* What is the impact of this pedagogical approach on students’ problem-solving skills and academic performance in

stoichiometry?

* Are there differences in learning outcomes when using traditional methods compared to the discovery learning model

with scaffolding?

## Methodology

This study will be conducted at Senior High School of Taganito Claver District during the first semester of the 2024/2025 Academic Year, in December. This study's demographic and sample were female students from class LAVOISER, with a total of 24 students in the experimental and control classes. This study employed a quasi-experimental design with nonequivalent pretest- posttest control groups. Table 1 presents an overview of this concept.

**Table 1.** Pretest-post-test control group design.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Students ID | PRE-TEST SCORE  (with percentage) | | POST-TEST SCORE  (with percentage) | |
| 001 | 14 | 70 | 17 | 85 |
| 002 | 13 | 65 | 18 | 90 |
| 003 | 15 | 75 | 17 | 85 |
| 004 | 12 | 60 | 15 | 75 |
| 005 | 16 | 80 | 19 | 95 |
| 006 | 18 | 90 | 20 | 100 |
| 007 | 11 | 55 | 14 | 70 |
| 008 | 17 | 85 | 18 | 90 |
| 009 | 15 | 75 | 17 | 85 |
| 010 | 18 | 90 | 19 | 95 |
| 011 | 13 | 65 | 16 | 80 |
| 012 | 16 | 80 | 18 | 90 |
| 013 | 15 | 75 | 17 | 85 |
| 014 | 18 | 90 | 19 | 95 |
| 015 | 12 | 60 | 14 | 70 |
| 016 | 17 | 85 | 19 | 95 |
| 017 | 14 | 70 | 15 | 75 |
| 018 | 19 | 95 | 20 | 100 |
| 019 | 13 | 65 | 16 | 80 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 020 | 16 | 80 | 18 | 90 |
| 021 | 10 | 50 | 14 | 70 |
| 022 | 12 | 60 | 13 | 65 |
| 023 | 13 | 65 | 15 | 75 |
| 024 | 11 | 55 | 13 | 65 |

PRE-TEST SCORE: Reflects the student’s performance before using the discovery learning model with scaffolding.

POST-TEST SCORE: Reflects the student’s performance after using the discovery learning model with scaffolding.

This table provides a snapshot of how students’ scores might change from pre-test to post-test when using the discovery learning model with scaffolding on stoichiometric materials.

The research was conducted in four stages: initial observation, preparation, implementation, and evaluation. This study's data collection methods included pretest-posttests and observation sheets. The test consists of 20 multiple-choice questions. Student activity observation sheets are distributed during learning utilizing the discovery learning approach and a scaffolding-based Student Worksheet.

## Description of Learning Outcomes

Table 2 provides an overview of student learning results based on the school's Assessment Reference Benchmarks (PAP).

**Table 2.** Categorization of student learning outcome.

|  |  |
| --- | --- |
| **Interval value** | **Criteria** |
| ≥84 | Very good |
| 74≤ - <84 | Good |
| 64≤ - <74 | Medium |
| 54≤ - <64 | Not good |
| <54 | Very less |

### *Determinant of Student Activity*

The score of the observation sheet filled in by the observer can be analyzed using the following formula:

*Percentage score* (%) = 𝑜𝑎 𝑐𝑜𝑟 𝑜𝑏𝑎𝑛𝑑 x 100%

𝑜𝑎 𝑐𝑜𝑟 𝑎

For interpretation of student activity scores, see Table 3.

**Table 3.** Interpreting student observation sheet scores.

|  |  |  |
| --- | --- | --- |
| **Criteria value** | **Percentage (%)** | **Category** |
| IV | 75 ≤ P ≤ 100 | Very good |
| III | 50 ≤ P ≤ 75 | Good |
| II | 25 ≤ P ≤ 50 | Less good |
| I | P < 25 | Not good |

* 1. ***Analysis of N-Gain Value***

To evaluate the efficacy of the teaching strategy used in the classroom, one can use the N-Gain formula presented by Arikunto (2003), which is calculated using the following formula:

N-Gain = 𝑐𝑜𝑟 𝑜−𝑐𝑜𝑟

𝑐𝑜𝑟 𝑎−𝑐𝑜𝑟𝑜

**Table 4.** N-Gain value category.

|  |  |
| --- | --- |
| **Score N-Gain** | **Category** |
| Value G ≥ 0.71 | High |
| 0.31 ≤ value G ≤ 0.71 | Medium |
| 0.31 ≤ value G ≤ 0.71 | Low |

As shown in Table 4, a value of n-gain (Value G) equal to or greater than 0.71 is classified as 'High.' This indicates a significant improvement in students' comprehension or skills,

implying that using the discovery learning model with scaffolding-based Student Worksheets in stoichiometry learning has significantly impacted the learning outcomes of class LAVOISIER students. The 'High' category indicates that many students have made significant gains in their understanding of stoichiometric materials. A score of n-gain between 0.31 and 0.71, on the other hand, is classified as 'Medium.' This indicates a moderate level of improvement in learning outcomes. While learners in this category have made progress, it may not be as noticeable as those in the 'High' category. The 'Medium' classification indicates that the educational approach's effectiveness should be improved further. Finally, when the n- gain value is less than 0.31, it is classified as 'Low.' This indicates a limited improvement in learning outcomes, implying that the application of the discovery learning model using scaffolding-based Student Worksheets may have had little impact on student understanding or skill development.

# Result & Discussion

Table shows the findings of the descriptive analysis based on pretest and post-test results.

According to the statistics in Table 5, the average pretest score in the experimental class was 22.88, and the average posttest score was 78.50. The low pretest score in the practical course was attributed to the students' initial conceptual difficulty with stoichiometry subject, which resulted in an inaccurate pretest responses. The multiple-choice format of the questions may have encouraged guessing, altering pupils' understanding. However, after treatment with the discovery learning model and scaffolding-based Student Worksheets, the experimental class's post-test scores improved considerably to 77.50, indicating greater learning outcomes.

**Table 5**. Description of pretest and post-test scores for experimental class and control class.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Experiment class** | | **Control class** | |
| **Pretest** | **Post-test** | **Pretest** | **Post-test** |
| Mean | 22.88 | 78.50 | 27.25 | 73.32 |
| Median | 21.00 | 81.00 | 26.00 | 76.00 |
| Modus | 21 | 81 | 26 | 71 |
| Std. deviation | 10.610 | 7.761 | 10.127 | 7.606 |
| Minimum | 0 | 66 | 11 | 56 |
| Maximum | 41 | 91 | 46 | 86 |

This progress is attributed to scaffolding-based media, which gives gradual assistance and practical applications of chemistry. In the control group, the average pretest score was

27.25 and the average post-test score was 73.32. The discovery learning approach, which encourages active participation in

learning activities, is responsible for the improved learning outcomes. However, the experimental class had higher post-test scores as a result of employing scaffolding-based Student Worksheet learning materials. Analyzing the minimum and maximum scores reveals that the practical and control classes had similar minimum pretest and top post-test scores. The minimal pretest results were in the deficient category, indicating the need for assistance in learning the topic. The post-test scores, while meeting the Minimum Completeness Criteria, showed that not all students grasped the acid-base subject satisfactorily. Examining metrics such as median and mode, it is clear that some students in both the experimental and control groups scored low, demonstrating the wide range of comprehension levels. The median and mode scores on the experimental class post-test and control class pretest were high, meeting the Minimum Completeness Criteria and indicating better learning outcomes. Meanwhile, the post-test results for the experimental and control classes were identical, with median scores of 80 and 70. This resemblance shows that numerous students in both categories improved their grasp of the same idea as they progressed from pretest to posttest.

Analyzing these data reveals that the mode value in the experimental class is high, meeting the minimum completeness criteria. In contrast, despite their high post-test results, the control group did not achieve the Minimum Completeness

Criteria. The standard deviation value, which measures data dispersion and proximity to the mean, is critical for understanding sample variability (Sekaran & Bougie, 2016). Table 5 shows that the pretest and post-test standard deviation values in the experimental and control classes are lower than the average, indicating minimal data deviation. This means that the data is more accurate and closely resembles the average value or mean. One significant aspect contributing to improved learning results in experimental and control classes was the strategic choice of learning models. Selecting an optimal learning model is critical for increasing student acceptance of the learning process, boosting learning outcomes, and supporting teachers in meeting their educational goals. Implementing the Discovery Learning paradigm, which is known for actively engaging students in learning activities (Martaida, Bukit, & Ginting, 2017; Putriani & Rahayu, 2018), improved learning results in both classrooms. However, the degree of improvement in the control class was slightly lower than in the experimental group. The observed improvement in academic achievement among the experimental group, compared to the control group, may be attributed to the implementation of the Discovery Learning strategy in conjunction with scaffolding- based Student Worksheets in the experimental classroom. The use of learning media is seen as an important predictor of academic progress in the classroom context. Learning Media as an Instructional Tool is imperative to facilitate the effective

and efficient communication of educational messages and lesson materials from educators to students. The use of media helps to consolidate abstract conceptions or ideas while also generating engagement and active participation among learners. The media facilitates critical thinking among students. Using engaging educational media helps capture students' attention and make learning more enjoyable (Pratama & Saregar, 2019). Class lavoisier’ student learning outcomes are classified as experimental and control.

**Table 6.** Categorizing student chemistry learning outcomes.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Interval score** | **Criteria** | **Experiment class** | | **Control class** | |
| **Frequenc**  **y** | **Percentag e**  **(%)** | **Frequency** | **Percentage**  **(%)** |
| >84 | Very  good | 8 | 33.33 | 3 | 12.5 |
| 74≤ - <84 | Good | 11 | 45.83 | 12 | 50 |
| 64≤ - <74 | Pretty  good | 5 | 20.83 | 8 | 33.33 |
| 54≤ - <64 | Not  enough | - | - | 1 | 4.16 |
| < 54 | Very  less | - | - | - | - |
| Total | | 24 | 100 | 24 | 100 |

As shown in Table 6, the student learning outcomes scores in the experimental and control classes are in the moderate, good, and very good categories, indicating that students were able to understand and master the material being taught; however, two students (4.16%) fell into the poor category. It shows that certain pupils in the experimental and control classes still need help grasping the stoichiometry subject that the teacher is teaching. The control class's Discovery Learning learning approach focuses on seeking for and solving existing problems. Nonetheless, some students are less interested and motivated to answer all of the teacher's difficulties and inquiries. Research undertaken by Istiqomah, Prasojo, and Arifa'i (2018) and Putri, Roza, and Maimunah (2020) regarding applying the Discovery Learning model to improve student learning outcomes, one obstacle was that students needed to be more diligent in making discoveries. Meanwhile, in the experimental class, student learning outcomes were in the quite good (20.83%), good (45.83), and very good (33.33) categories worksheets. This shows how the discovery learning approach with scaffolding-based Student Worksheets affects student learning outcomes. Student worksheet T with a scaffolding strategy that encourages students to think with many instructions and provides the necessary assistance on certain materials will make it easier for students to understand the concept of the material being studied because scaffolding provides structured assistance to students at the start of learning and then

gradually activates it. Budaeng, Ayu, and Pratiwi (2017) suggest that students learn more autonomously to better understand the subject content.

### *Description of Learning Implementation Observation Results*

* + 1. ***Teacher Teaching Activities***

Observers tracked the outcomes of teacher instructional activities over the course of four meetings. Observations were undertaken to see how the discovery learning paradigm was used in conjunction with scaffolded Student Worksheets. Table 7 shows the observation findings from teacher teaching activities in class LAVOISIER, which was an experimental class*.*

**Table 7.** Observation results of teachers' teaching activities in class LAVOISIER female.

|  |  |  |
| --- | --- | --- |
| **Meeting to** | **Teacher activity implementation (%)** | **Criteria** |
| I | 77.6 % | Very good |
| II | 82.1% | Very good |
| III | 91% | Very good |
| IV | 93 | Very good |
| Average | 86% | Very good |

Table 7 shows the gradual increase in the implementation % of all observable features as the instructor provided learning material utilizing the discovery learning paradigm and scaffolding-based Student Worksheets. The increase was significant, advancing from the first to the third meeting with an impressive average percentage of 86%, categorizing it as ‘very good.' The teacher's expert use of this model contributed to increased student interest in the presented learning material, a critical factor influencing their active participation in the learning process. This emphasizes the importance of teachers presenting material in accordance with the applied model. Analyzing the score interpretations for teacher teaching activities, the first meeting achieved a noteworthy 76.6%, describing it as very good.' The researcher's previous interaction with educators contributed to this successful start. However, despite the positive categorization, the initial meeting revealed areas for improvement, particularly in guiding students to exchange ideas in problem- solving actively. Student apathy to the learning process demanded ongoing efforts to guide them in discussing the disseminated Student Worksheet difficulties. Furthermore, the teacher continued to struggle with allocating time for all learning activities. The following meetings, namely the second, third, and fourth, demonstrated a remarkable overall achievement of observed features, with average percentages of 82.1%, 91%, and 93%, respectively. This evolution proved the

teacher's capacity to adjust to class settings and students by aligning the syntax in the learning model with time allocation for better learning implementation. The teacher's capacity to govern and supervise individual student thinking, facilitate group discussions, and encourage the presentation or sharing of group outcomes created an environment in which students were actively engaged in the learning experience. This consistent development demonstrated the teacher's dedication to improving the teaching method and optimizing the learning experience for students.

**Table 8**. Observation results of student learning activities in class LAVOISIER female.

|  |  |  |
| --- | --- | --- |
| **Meeting to** | **Student learning activity (%)** | **Criteria** |
| I | 75 % | Good |
| II | 81% | Very good |
| III | 85% | Very good |
| IV | 92% | Very good |
| Average | 83.25% | Very good |

### *Student Learning Activities*

The outcomes of student learning activities assessed during learning included three meetings. The observer watches student learning activities in the experimental class using the

discovery learning approach, which is supported by scaffolding- based Student Worksheets. Table 8 shows the outcomes of observing students' learning activities in class LAVOISIER, which was an experimental class. Table 8 displays the percentage of student learning activities in class. According to Ayustiani, Aceng, and Yuniati (2021), one aspect that helps students to participate actively in the learning process is their enthusiasm in the lessons delivered by their teachers. As a result, if pupils are less interested in the learning process, their activity levels will increase, and vice versa. Students will be highly engaged if they feel interested in the teaching and learning process. Based on the categorization of score interpretations for student learning activities at the first meeting, it was clear that student activities were in the good category, with a percentage of 75%. Even if it is in a good category, many elements require optimization and improvement. At the first meeting, students still had to adjust to the Discovery Learning approach, which was aided by the scaffolding-

based Student Worksheet. Not all students can collaborate well with their partners or group friends to solve and debate the tasks assigned. Aside from that, no group dared to offer to share the outcomes of their discussion, therefore multiple groups had to be assigned to speak in front of the class. At the second, third, and fourth meetings, it increased to 81%, 85%, and 92% in the very good category, indicating that students were getting used to and could follow learning

according to the syntax of the discovery learning model using scaffolding-based Student Worksheets. In the ongoing learning process, they are active and ask each other questions when discussing problems. Please keep in mind that talking to peers is the greatest choice if students are reluctant approaching and sharing thoughts with the teacher directly. Because they are engaging with ordinary friends, they will not be embarrassed or frightened to discuss their responses and ideas. Aside from that, practically all groups were willing to volunteer to present the outcomes of their talks in front of the class. It is a step forward for students compared to the last meeting, while some still need to feel more comfortable presenting the outcomes of group work in class and be appointed to continue forward. According to the study of the results of observations of student activities, the achievement of all aspects examined was 82.25%, including the very good category. Thus, student activity in the learning process increases successively from the first to the third in a series of learning activities using the discovery learning model using scaffolding-based Student Worksheets.

### *N-Gain Analysis*

We used N-gain analysis to determine how well the discovery learning model with scaffolding-based Student Worksheet worked with class LAVOISIER students at Senior High School of Taganito, Claver, Surigao del Norte. The results s howed that the

experimental class (class Lavoisier) learned more than the control class (Class).

**Table 9**. Learning effectiveness category for class LAVOISIER female (Experimental class) and class Lavoisier Men (Control class).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Informatio n** | **Experiment class** | | | **Control class** | | |
| **Pretest** | **Post-**  **test** | **N-Gain** | **Pretes**  **t** | **Post-**  **test** | **N-Gain** |
| Total student | 24 | | | 24 | | |
| Average | 21.88 | 77.50 | 0.72 | 26.25 | 72.92 | 0.64 |
| Category | Medium | | | Medium | | |

Table 9 for the experimental class shows the efficiency of combining the discovery learning approach with scaffolding- based Student Worksheets. The N-Gain value falls into the middle category. In comparison, the control class has a pretest value of 26.25, a posttest value of 72.92, and an N-Gain of 0.64, which is classified as medium. The N-Gain figures show that the efficacy levels in the experimental and control groups are impressive. However, the N-Gain value for student learning outcomes in the practical type exceeds that of the control class, leading to the conclusion that employing the discovery learning model with scaffolding-based Student Worksheets for stoichiometric material is considered more effective than learning solely through the Discovery Learning model without assistance, as it yields higher N- Gain value. The heightened

learning outcomes in the experimental class may be attributed to students actively engaging in discovery learning using scaffolding-based Student Worksheets (Amin, Madjdi, Ardianti, & Gung, 2021; Linggile, Supartin, & Payu, 2022). This strategy encourages students to take the initiative, solve problems, and collaborate with their peers. McNeill and Krajcik (2009) and Belland, Glazewski, and Richardson (2008) found that using a scaffolding method in Student Worksheets improved students' conceptual knowledge and capacity to execute activities independently. Students can dramatically expand their conceptual understanding by using scaffolding-based Student Worksheets, with a 91% success rate (Pratama & Saregar, 2019). This demonstrates the effectiveness of including scaffolding in learning materials to promote a more interesting and successful learning experience.

# Conclusion

This study demonstrates that incorporating discovery learning with scaffolded worksheets significantly improves student understanding of stoichiometry. The experimental group, utilizing this approach, achieved a normalized gain (N-gain) of 0.72, indicating a substantial learning gain compared to the control group’s N-gain of 0.64 this difference suggests that the discovery learning methodology, supported by structured worksheets, fostered a more effective learning environment, leading to improved comprehension and application of stoichiometric principles. The results support the implementation of active learning strategies, such as discovery

learning with appropriate scaffolding, to enhance student

performance in stoichiometry and potentially other challenging scientific concepts. Further research could explore the optimal level of scaffolding and the long-term retention of knowledge gained through this approach. The Class Lavoisier Grade 11 of Taganito National High School applies discovery learning with scaffolding based- worksheets based on the results obtained with an average score of 72.92, with the lowest score being 55 and the highest being 85. Applying the Discovery Learning model using scaffolding-based Student Worksheets effectively improved results. The learning of class with students who are taught the Discovery Learning model without using scaffolding- based Student Worksheet.

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