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Application of the discovery learning model using student worksheets based on scaffolding on stoichiometric materials to improve learning outcomes

Maysara[1]♣
Wa Ode Aulia Wahyuni[2]
Muh. Alim Marhadi[3]
Dahlan[4]
Aceng Haetami[5]
Esnawi[6]

[1,2,3,4,5,6]*Department of Chemistry Education, Universitas Halu Oleo, Kendari, Indonesia.*
[1]*Email: maysara.fkip@uho.ac.id*
[2]*Email: auliawahyuni978@gmail.com*
[3]*Email: alim.mahardi@uho.ac.id*
[4]*Email: dahlan.fkip@uho.ac.id*
[5]*Email: acenghaetami@uho.ac.id*
[6]*Email: esnawi.fkip@uho.ac.id*

Abstract

This research endeavours to achieve three primary objectives: firstly, to assess the learning outcomes of class X students instructed through the discovery learning model and class; secondly, to evaluate the effectiveness of these learning outcomes; and thirdly, to discern any significant differences in learning outcomes between students taught through the standard discovery learning model and those taught with the incorporation of a scaffolding-based Student Worksheet. The research method employed is quasi-experimental, utilizing a non-equivalent pretest-post-test control group design to gather comprehensive insights. Data collection involves the strategic use of pre-tests, post-tests, and observation sheets to capture nuanced aspects of the learning process. The findings of the research indicate that the application of the discovery learning model, complemented by scaffolding-based Student Worksheets in stoichiometry learning, has a transformative impact. It is observed that students exposed to this method exhibit heightened engagement, reflected in their learning activities categorized as 'very good.' The calculated learning effectiveness, quantified by a substantial n-gain value of 0.71, attests to the high efficacy of this pedagogical approach, placing it in the 'high' category. These results carry significant implications for educational practitioners and curriculum developers. Educators can leverage the discovery learning model augmented with scaffolding-based Student Worksheets to enhance student participation and comprehension in stoichiometry. The demonstrated effectiveness of this approach suggests its potential integration into chemistry education methodologies, promising improved learning outcomes.

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(♣ *Corresponding Author*)

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1. Introduction

Chemistry is a lesson with abstract material; one example is stoichiometry (Sappaile, 2019). Abstract chemistry material tends to make it difficult for students to understand the lesson, so students cannot learn actively. Generally, students learn by rote rather than actively seeking to build their understanding of the concept. A correct understanding of the basic concepts that build these concepts is required to understand chemistry concepts. For this reason, meaningful learning conditions are necessary so that students can understand the concept of stoichiometry well (Nahum, Hofstein, Mamlok-Naaman, & Ziva, 2004; Taber, 2000).

Based on the results of interviews with chemistry educators at Senior High School Qur'an Wahdah Islamiyah Kendari, which were held on June 10, 2022, Senior High School Qur'an Wahdah Islamiyah Kendari implemented the 2013 curriculum, and students' mastery of concepts is still low. This can be seen in learning outcomes (daily tests). According to the Chemistry educator who teaches in class, another obstacle faced when students study stoichiometry material is the limited learning resources and learning media that can make it easier for students to learn. Based on this reality, learning media are needed to improve and support the quality of learning on stoichiometric material. Teachers have a very important role in overcoming this problem. One alternative teachers can use to produce an innovative and enjoyable learning process is learning models and media that suit students' needs and difficulties in understanding lessons and working on questions. One model that can be used is a discovery learning model assisted by scaffolding-based Student Worksheets.

The application of the discovery learning model is effective for chemical problem-solving abilities. The guided discovery learning model significantly influences students' critical thinking skills in learning, stimulates students to think creatively, and helps students discover new knowledge or concepts in chemistry; the learning atmosphere is more enjoyable and more challenging for students to discover their concepts (Kawuri & Fayanto, 2020; Nurfadilah, Maruto, & Fayanto, 2020; Sahara, Nafarudin, Fayanto, & Tairjanovna, 2020). Moreover, students can practice science process skills (Yondriadi & Yerimadesi, 2019). Apart from effective learning models, learning media are also needed to support success in teaching and learning.

Learning media is one of the supporting factors in the learning process (Fayanto, Misrawati, Sulisworo, Istiqomah, & Sukariasih, 2019). One learning medium that can be adapted to students' ability levels is a scaffolding-based Student Worksheet The combination of Student Worksheets with scaffolding Fathiyah, Irianti, Azizahwati, and Yennita (2019) and Mahtari, Wati, Hartini, Misbah, and Dewantara (2020), which encourages 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 studied because scaffolding provides structured assistance to students at the beginning of learning and then gradually activates it. Students learn independently so that they understand the subject matter better. The Student Worksheet's projection of aspects of students' conceptual understanding makes the objectives of implementing Student Worksheets clearer (Pratama & Saregar, 2019). Based on these problems, the researcher is interested in researching Application of the Discovery Learning Model Using Scaffolding-Based Student Worksheets on Stoichiometric Material for Class X Students of Senior High School Qur'an Wahdah Islamiyah Kendari.

2. Method

This research will be carried out at Senior High School Qur'an Wahdah Islamiyah Kendari in the even semester of the 2022/2023 Academic Year in May. The population and sample in this study were class X_{MIPA} Female, totaling 24 students in the experimental class and class. The method used in this research is Quasi-Experimental Design using Nonequivalent Pretest-Posttest Control Group Design. An overview of this design can be seen in Table 1.

Table 1. Non-equivalent pretest-post-test control group design.

Group	Pre-test	Treatment	Post-test
Experiment	O_1	X	O_2
Control	O_1	Y	O_2

This research was carried out in four stages: the initial stage observation, preparation stage, implementation stage, and evaluation stage. The data collection techniques used in this research were pretest-post-test and observation sheets. The test questions are given in multiple-choice form, totalling 20 questions. Student activity observation sheets are given during learning using the discovery learning model using a scaffolding-based Student Worksheet.

2.1. Description of Learning Outcomes

An overview of student learning outcomes by the school's Assessment Reference Benchmarks (PAP) can be seen in Table 2.

Table 2. Categorization of student learning outcome.

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

2.2. Determinant of Student Activity

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

$$\textit{Percentage score}\ (\%) = \frac{total\ score\ obtained}{total\ score\ maximum} \times 100\%$$

For interpretation of student activity scores, see Table 3.

Table 3. Interpreting student observation sheet scores.

Criteria value	Percentage (%)	Category
4	76 ≤ P ≤ 100	Very good
3	51 ≤ P ≤ 76	Good
2	26 ≤ P ≤ 51	Less good
1	P < 26	Not good

2.3. Analysis of N-Gain Value

In order to assess the efficacy of the instructional approach employed in the classroom, one can employ the N-Gain formula as proposed by Arikunto (2003), which is determined using the following formula:

$$\text{N-Gain} = \frac{score\ posttest - score\ pretest}{score\ maximum - scoreposttest}$$

Table 4. N-Gain value category.

Score N-Gain	Category
Value G ≥ 0.70	High
0.30 ≤ value G ≤ 0.70	Medium
0.30 ≤ value G ≤ 0.70	Low

Based on Table 4, A value of n-gain (Value G) equal to or greater than 0.70 is categorized as 'High.' This indicates a substantial improvement in students' comprehension or skills, suggesting that applying the discovery learning model using scaffolding-based Student Worksheets in stoichiometry learning has significantly impacted the learning outcomes of class X_{MIPA} students. The 'High' category signifies that many students have experienced notable advancement in their understanding of stoichiometric materials. On the other hand, a value of n-gain falling within the range of 0.30 to 0.70 is categorized as 'Medium.' This implies a moderate level of improvement in learning outcomes. While students in this category have shown progress, it may not be as pronounced as those in the 'High' sort. The 'Medium' classification suggests that there is room for further enhancement in the effectiveness of the instructional approach. Lastly, when the n-gain value is less than 0.30, it is categorized as 'Low.' This indicates a limited improvement in learning outcomes, suggesting that the application of the discovery learning model using scaffolding-based Student Worksheets may have had a minimal impact on student understanding or skills development.

3. Result & Discussion

The results of the descriptive analysis obtained from the pretest and post-test results can be seen in Table 5.

Based on the data presented in Table 5, the average pretest score in the experimental class was 21.88, with an average post-test score of 77.50. The initial low pretest score in the practical course was attributed to the students' initial conceptual challenges with stoichiometry material, resulting in incorrect responses to the pretest questions. The multiple-choice format of the questions may have led to guesswork, obscuring the students' understanding. However, following treatment through the discovery learning model using scaffolding-based Student Worksheets, the post-test results for the experimental class significantly improved to 77.50, indicating enhanced 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	21.88	77.50	26.25	72.92
Median	20.00	80.00	25.00	75.00
Modus	20	80	25	70
Std. deviation	10.510	7.661	10.027	7.506
Minimum	0	65	10	55
Maximum	40	90	45	85

This improvement is attributed to the scaffolding-based media, which provides gradual assistance and practical examples of chemistry in everyday life. In the control class, the average pretest score was 26.25, and the average post-test score was 72.92. The increase in learning outcomes is attributed to the discovery learning model, fostering active engagement in learning activities. However, the post-test scores were higher in the experimental class due to using scaffolding-based Student Worksheet learning media. Analyzing the minimum and maximum scores, it is evident that the practical and control classes had similar minimum pretest and top post-test scores. The minimum pretest scores fell into the deficient category, highlighting the need for support in understanding the material. The post-test scores, while meeting the Minimum Completeness Criteria, indicated that not all students understood the acid-base material satisfactorily. Examining measures such as median and mode, it is observed that some students in both the experimental and control classes had low scores, emphasizing the diverse comprehension levels. The median and mode scores in the experimental class post-test and control class pretest were high, meeting the Minimum Completeness Criteria, indicating improved learning outcomes. Meanwhile, the experimental and control classes' post-test revealed identical mode scores, registering 80 and 70. This similarity suggests a collective improvement in understanding the same concept among several students in both categories, transitioning from pretest to post-test. Analyzing these data, it becomes evident that the mode value in the experimental class is high, meeting the minimum completeness criteria. Conversely, the post-test scores in the control class, although high, fell short of meeting the Minimum Completeness Criteria. The standard deviation value, a measure of data distribution and proximity to the mean, plays a crucial role in understanding the variability within a sample (Sekaran & Bougie, 2016). In Table 5, the pretest and post-test standard deviation values in the experimental and control classes are smaller than the average, indicating minimal data deviation. This implies that the data tends to be more accurate and exhibits increased similarity to the average value or mean. One key factor contributing to the enhanced learning outcomes in experimental and control classes was the strategic choice of learning models. Selecting an optimal learning model is paramount, fostering student acceptance of the learning process, improving learning outcomes, and assisting teachers in achieving their educational objectives. Implementing the Discovery Learning model, known for engaging students actively in learning activities (Martaida, Bukit, & Ginting, 2017; Putriani & Rahayu, 2018) increased learning outcomes in both classes. However, the degree of improvement in the control class was slightly lower than in the experimental category. Compared to the control group, the observed improvement in academic performance among the experimental group may be attributed to implementing the Discovery Learning approach in conjunction with scaffolding-based Student Worksheets in the experimental class. The utilization of learning media is considered a crucial determinant of academic achievement within the classroom setting. 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 utilization of media aids in solidifying abstract notions or ideas and catalyses stimulating engagement and active participation among learners. Media serves as a conduit for critical thinking among pupils. Using engaging educational media can captivate students' attention and foster a sense of enjoyment in the learning process (Pratama & Saregar, 2019). The categorization of student learning outcomes for Class X_{MIPA} Putri as an experimental class and a control class.

Table 6. Categorizing student chemistry learning outcomes.

Interval score	Criteria	Experiment class		Control class	
		Frequency	Percentage (%)	Frequency	Percentage (%)
>84	Very good	7	29.16	2	8.33
74≤ - <84	Good	10	41.66	11	45.83
64≤ - <74	Pretty good	7	29.16	9	37.5
54≤ - <64	Not enough	-	-	2	8.33
< 54	Very less	-	-	-	-
Total		24	100	24	100

Based on the Table 6 it can be seen that the student learning outcomes scores in the experimental class and control class are in the moderate, good, and very good categories, indicating that students have been able to understand and master the material being taught; there were still students in the poor category, namely 2 (8.33%). It demonstrates that some students in the experimental and control classes still require assistance understanding the stoichiometry material that the teacher is teaching. The Discovery Learning learning model in the control class emphasizes searching and finding answers to existing problems. Still, some students have less interest and motivation in answering all the problems and questions the teacher gives. In research conducted 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 (29.16%), good (41.66), and very good (29.16) categories worksheets. This shows that the discovery learning model using scaffolding-based Student Worksheets influences student learning outcomes. Student worksheet T with a scaffolding strategy that encourages 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 studied because scaffolding is assistance to students in a structured manner at the beginning of learning and then gradually activates it. Students learn independently better to understand the subject matter (Budaeng, Ayu, & Pratiwi, 2017).

3.1. Description of Learning Implementation Observation Results

3.1.1. Teacher Teaching Activities

Observers monitored the results of teacher teaching activities during the learning process, which consisted of four meetings. Observations were conducted to see the implementation of learning using the discovery learning model assisted by Student Worksheets based on scaffolding. Observation results from teacher teaching activities in class X_{MIPA} Putri as an experimental class can be seen in Table 7.

Table 7. Observation results of teachers' teaching activities in class X_{MIPA} female.

Meeting to	Teacher activity implementation (%)	Criteria
I	76.6 %	Very good
II	81.1%	Very good
III	90%	Very good
IV	92%	Very good
Average	85%	Very good

Table 7 illustrates the progressive improvement in the implementation percentage of all observed aspects as the teacher delivered learning material by applying the discovery learning model using scaffolding-based Student Worksheets. The increase was notable, advancing from the first to the third meeting, with an impressive average percentage of 85%, categorizing it as 'very good.' The teacher's adept use of this model contributed to heightened student interest in the presented learning material, a crucial factor influencing their active participation in the learning process. This underscores the importance of teachers delivering material in alignment with the applied model. Analyzing the score interpretations for teacher teaching activities, the first meeting achieved a commendable 76.6%, categorizing it as 'very good.' The researcher's prior discussion 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 indifference to the learning process necessitated continued efforts to direct them in discussing the distributed Student Worksheet problems. Additionally, optimizing time allocation for all learning processes remained challenging for the teacher. Subsequent meetings, namely the second, third, and fourth, showcased an impressive overall achievement of observed aspects, with average percentages of 81.1%, 90%, and 92%, respectively. This progression demonstrated the teacher's adaptability to class conditions and students, aligning the syntax in the learning model with time allocation for enhanced learning implementation. The teacher's ability to control and supervise individual student thinking, facilitate group discussions, and encourage the presentation or sharing of group results fostered an environment where students actively engaged in the learning process. This sustained improvement showcased the teacher's commitment to refining the teaching approach and optimizing the learning experience for students.

Table 8. Observation results of student learning activities in class X_{MIPA} female.

Meeting to	Student learning activity (%)	Criteria
I	74 %	Good
II	80%	Very good
III	84%	Very good
IV	91%	Very good
Average	82.25%	Very good

3.1.2. Student Learning Activities

The results of student learning activities observed during learning consisted of three meetings. The observer observes student activities in learning in the experimental class by applying the discovery learning model assisted by Student Worksheets based on scaffolding. The results of observing students' learning activities in class X_{MIPA} Putri as an experimental class can be seen in Table 8. Table 8 shows the percentage of students' learning activities in class. One of the factors that encourages students to participate actively in the learning process, according to Ayustiani, Aceng, and Yuniati (2021), is their interest in the lessons their teachers deliver. Therefore, if students feel less interested in the learning process, student activity will be higher, and vice versa. Student activity will be high if students feel interested in the teaching and learning process.

Based on the categorization of score interpretations on student learning activities at the first meeting, it could be seen that student activities were in a good category with a percentage of 74%. Even though it is in a good category, many aspects still need to be implemented optimally and improved. At the first meeting, students still needed to adjust to the Discovery Learning model, assisted by the scaffolding-based Student Worksheet that was applied. Not all students can work optimally with their partners or group friends to solve and discuss the problems given. Apart from that, no group dared to volunteer to present the results of their discussion, so several groups had to be appointed to come to the front of the class. At the second, third, and fourth meetings, it increased to 80%, 84%, and 91% 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 note that talking to peers is the best option if students feel awkward and are reluctant to approach and give ideas to the teacher directly. Because they are dealing with ordinary friends, they will not feel embarrassed or afraid to explore their answers and opinions. Apart from that, almost all groups dared to volunteer to present the results of their discussions in front of the class. It is progress for students compared to the previous meeting, although some still need to be more comfortable presenting the results of group work in class and still need to be appointed to move forward. Based on the analysis of the results of observations of student activities, the achievement of all aspects observed was 82.25%, including in 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.

3.2. N-Gain Analysis

We used N-gain analysis to determine how well the discovery learning model with scaffolding-based Student Worksheet worked with class X_{MIPA} Putri students at Senior High School Qur'an Wahdah Islamiyah Kendari. The results showed that the experimental class (class X_{MIPA} Putri) learned more than the control class (Class).

Table 9. Learning effectiveness category for class X_{MIPA} female (Experimental class) and class X_{MIPA} Men (Control class).

Information	Experiment class			Control class		
	Pretest	**Post-test**	**N-Gain**	**Pretest**	**Post-test**	**N-Gain**
Total student	24			24		
Average	21.88	77.50	0.71	26.25	72.92	0.63
Category	Medium			Medium		

Table 9 for the experimental class provides a glimpse into the effectiveness of implementing the discovery learning model with scaffolding-based Student Worksheets. The N-Gain value falls within the medium category. In comparison, the control class exhibits a pretest value of 26.25, a posttest value of 72.92, and an N-Gain of 0.63, also categorized as medium. Assessing the N-Gain values indicates that the effectiveness levels in the experimental and control classes are commendable. However, the N-Gain value for student learning outcomes in the practical type surpasses 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 a 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 approach encourages students to take initiative, find solutions to given problems, and collaborate with their peers. Research by McNeill and Krajcik (2009) and Belland, Glazewski, and Richardson (2008) supports the notion that implementing a scaffolding approach in Student Worksheets can enhance students' conceptual understanding and ability to complete tasks independently. Utilizing scaffolding-based Student Worksheets, students can significantly increase their knowledge of concepts, achieving a success rate of 91% (Pratama & Saregar, 2019). This underscores the efficacy of incorporating scaffolding in learning materials to facilitate a more engaging and effective learning process.

4. Conclusion

In the chemistry learning results in class X_{MIPA} Putri on the stoichiometry material taught using the Discovery Learning model, a picture of student learning outcomes was 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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