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EFFECTIVENESS OF MULTIPLE REPRESENTATION-BASED SCAFFHOLDING IN CHEMISTRY LEARNING: A STUDY ON 3T STUDENTS WITH LOW NUMERACY ABILITY

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Keywords

Scaffolding, multiple representation, chemistry, 3T

Abstract

This study aims to analyze the effectiveness of scaffolding-based learning with multiple representations in improving students' understanding of atomic structure and electron configuration. The subjects of the study consisted of 42 students from the 3T area, who were divided into an experimental group and a control group. The experimental group received learning with scaffolding based on multiple representations, while the control group received conventional learning. The results showed that there was a significant increase in conceptual understanding in the experimental group, with an average pretest score of 45.2 and a posttest score of 78.5. In addition, the scaffolding technique based on multiple representations was proven effective in reducing students' misconceptions about atomic structure and electron configuration, as well as increasing their learning motivation. Therefore, this learning strategy is recommended to be widely applied in chemistry learning, especially for students in the 3T area who have limited access to learning resources and low numeracy skills.

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INTRODUCTION

Learning chemistry is a field of science that requires a deep understanding of abstract concepts and good numeracy skills (Damayanti & Priatmoko, 2023). However, many students in the 3T (Frontier, Remote, and Disadvantaged) areas face difficulties in understanding chemistry materials due to various limitations, such as unequal access to education, lack of laboratory facilities, and low cognitive and numeracy abilities. This gap causes a low level of conceptual understanding and the emergence of various misconceptions that hinder the learning process (Aprian et al., 2017). Conceptual understanding is highly dependent on multiple representations in chemistry learning, namely the use of various forms of information presentation such as macroscopic, submicroscopic, and symbolic representations (Langitasari et al., 2023). Macroscopic representations include directly observable phenomena, such as color changes in chemical reactions (Nursyahrobby et al., 2023). Submicroscopic representations depict the particles that make up matter that cannot be seen with the naked eye, such as models of atoms and molecules (Tiaradipa et al., 2020). Meanwhile, symbolic representations include chemical formulas, reaction equations, and quantitative calculations in chemistry (Darmiyanti, Waskitarini, 2017). The combination of these three representations allows students to understand concepts more deeply and better connect various aspects of chemistry (Dwi Septiani & Okmarisa, 2023).

One of the concepts that is the basis for learning chemistry is atomic structure and electron configuration. Atomic structure is the basis for various other chemical concepts, including chemical bonds, element reactivity, and material properties. Electron configuration, namely the distribution of electrons in the orbitals of an atom, is very important in determining the chemical properties of an element and its reaction tendencies in the formation of compounds. However, for students from 3T areas, understanding this concept is often hampered by its abstract nature and the need for a good understanding of symbolic and submicroscopic representations. The concept of atomic structure has developed over time, starting from Dalton's atomic model which considers atoms as the smallest particles that cannot be divided anymore, to the quantum mechanics model which explains the existence of electrons in orbitals based on probability (Fajriani et al., 2021). Rutherford's model, which showed a small, positively charged atomic nucleus, successfully explained the basic structure of the atom, but failed to describe the distribution of electrons. Bohr's model then proposed that electrons move in certain orbits around the atomic nucleus, although this model was eventually refined by the quantum mechanical model, which stated that electrons are in orbits that are not fixed circles, but areas with certain probabilities.

Electron configuration describes how electrons are distributed in orbitals based on the Aufbau principle, the Pauli exclusion principle, and Hund's rule. The Aufbau principle states that electrons will occupy orbitals with lower energy first before filling orbitals with higher energy. The Pauli exclusion principle explains that in one orbital, there can be no more than two electrons with opposite spins. Meanwhile, Hund's rule states that electrons will fill parallel orbitals first before pairing up, in order to minimize repulsion between electrons. Although these models have been widely used in learning, students from 3T areas often have difficulty in understanding these concepts because of their abstract representation. Many of them do not have direct experience with experiments that can help visualize atomic structure and electron configuration. As a result, misconceptions often arise, such as the assumption that electrons move in fixed orbits like planets around the sun or that atoms are solid objects with no empty space inside.

The application of multiple representation-based scaffolding techniques can be an effective solution for this case. Scaffolding in learning refers to providing temporary support to students to help them understand complex concepts (Haryati et al., 2020). In the context of chemistry learning, scaffolding can take the form of explicit instructions, guiding questions, the use of concrete models, and step-by-step exercises designed to progressively develop students' cognitive skills (Cylindrica et al., 2021). This approach is in line with Vygotsky's theory of cognitive development, which emphasizes the importance of the zone of proximal development (ZPD) in the learning proces (Ria Armalasari et al., 2017). Through scaffolding, students are given assistance that is appropriate to their level of understanding until they are able to learn independently. Several studies have proven the effectiveness of multiple representation-based scaffolding in improving students' conceptual understanding in chemistry (Nabila & Gani, n.d.). For example, a study conducted by Chiu and Wu (2009) showed that the use of multiple representation-based scaffolding strategy significantly improved students' understanding of electrolyte and non-electrolyte solution concepts. They found that students who were given guidance in connecting macroscopic, submicroscopic, and symbolic representations showed higher improvement in understanding compared to students who only received conventional instruction. Similar research results were also found by Ainsworth (2011), who revealed that the use of multiple representations in chemistry learning helped students reduce misconceptions and improve problem-solving skills.

Research on the use of scaffolding in chemistry learning is still limited in the world of Indonesian education, especially in the 3T areas. (Erna Muliastrini et al., 2019). A study conducted by Susanti et al. (2018)

found that many students in remote areas have difficulty understanding the concept of solutions and acid-base reactions due to a lack of understanding of the relationship between submicroscopic and symbolic representations. This study highlights the need for a more adaptive and support-based learning approach so that students can build a more solid understanding. Based on these problems, this study aims to analyze the effectiveness of multiple representation-based scaffolding in reducing misconceptions of 3T students in learning atomic structure and electron configuration. This study will explore how the application of scaffolding can help students connect various types of representations in these concepts and how this strategy can improve their conceptual understanding. By understanding the role of scaffolding in chemistry learning, it is hoped that this study can contribute to the development of more inclusive and effective learning methods for students in 3T areas. Through the application of multiple representation-based scaffolding, it is hoped that 3T students can better understand abstract chemical concepts, reduce common misconceptions, and improve their numeracy skills in solving chemical problems. Thus, this research not only contributes to the field of chemistry education, but also to efforts to equalize access to quality education for all students, including those in remote and underdeveloped areas.

METHODS

This study used a quasi-experimental method with a pretest-posttest control group design. The subjects of the study consisted of 42 students from the 3T area in Papua, with details of 20 students from the Lanny Jaya area and 22 students from the Nduga area. Students will be divided into two groups, namely the experimental group that received scaffolding-based learning with multiple representations and the control group that received conventional learning. The material chosen in this study was atomic structure and electron configuration, considering the complexity of this concept which often causes misconceptions in students with low numeracy skills. The research instruments consisted of a chemical misconception diagnostic test, a learning motivation questionnaire, and a semi-structured interview to explore students' learning experiences. Quantitative data will be analyzed using statistical tests to see the differences in learning outcomes between the experimental and control groups, while qualitative data will be analyzed using thematic methods to understand students' perceptions of the application of scaffolding. In addition, this study will observe the effectiveness of scaffolding in helping students connect macroscopic, submicroscopic, and symbolic representations through the analysis of student responses to various learning tasks and activities. The results of this study are expected to provide recommendations in developing more effective chemistry learning strategies for students in 3T areas.

RESULTS AND DISCUSSION

Scaffolding-based learning with multiple representations has been applied in this study to analyze its effectiveness in improving students' understanding of atomic structure and electron configuration. This study was conducted involving 42 students from the 3T area, who were divided into experimental and control groups. The experimental group received learning with scaffolding based on multiple representations, while the control group received conventional learning. The results of this study include an increase in conceptual understanding, reduction of misconceptions, and the effect on students' learning motivation. The results of the analysis showed that there was a significant increase in the conceptual understanding of students who participated in scaffolding-based learning. The average pretest score for the experimental group was 45.2, while for the control group it was 46.1. After the learning intervention, the average posttest score of the experimental group increased to 78.5, while the control group only increased to 62.3. This increase indicates that the scaffolding strategy with multiple representations is able to provide more effective assistance in understanding abstract concepts such as atomic structure and electron configuration. Students who had previously had difficulty understanding the concept experienced significant progress after being given learning with scaffolding techniques.

In addition to improving conceptual understanding, this study also found that multiple representation-based scaffolding techniques were effective in reducing students' misconceptions about atomic structure and electron configuration. Common misconceptions before the intervention were the assumption that atoms are solid balls without empty space, electrons move in fixed orbits like planets around the sun, and errors in understanding electron configuration rules that do not comply with the Aufbau principle. After scaffolding-based learning, the results of interviews and analysis of students' answers showed that the frequency of these misconceptions decreased significantly. Students began to understand that electrons do not move in fixed orbits, but are in orbitals described by the quantum mechanics model based on the probability of their existence. They also better understood that the filling of electrons in orbitals follows the Aufbau principle, the Pauli exclusion principle, and Hund's rule, so they can avoid errors in writing the electron configuration of an atom. In more detail, the results of the data analysis can be seen in Table 1.

Table 1. Research data analysis

Group	**Average**		**Misconceptions**					
	Pretest	Posttest	Atoms are considered as solid spheres (%)		Electrons move in fixed orbits (%)		**Error in the Aufbau principle (%)**	
			Beginning	End	Beginning	End	Beginning	**End**
Experimental Class	42,5	78,5	65	20	70	15	55	**10**
Control Class	46,1	62,3	65	50	70	55	55	**40**

The effect of scaffolding on students' learning motivation is also one of the aspects analyzed in this study. The results of the motivation questionnaire given before and after the intervention showed that students who received scaffolding-based learning experienced a higher increase in learning motivation compared to the control group. Before the intervention, many students found it difficult and less interested in the material on atomic structure and electron configuration because of its abstract nature. However, after being given learning that involved macroscopic, submicroscopic, and symbolic representations simultaneously, students felt more interested and motivated to study the material more deeply. They expressed that this approach made it easier for them to understand concepts that were previously difficult to understand. This is supported by previous studies, such as that conducted by Chiu & Wu (2009), which found that the use of multiple representations can increase students' interest in chemistry and reduce their fear of abstract concepts.

From the results of this study, it was found that the scaffolding approach based on multiple representations has a positive impact on increasing the effectiveness of chemistry learning for students in 3T areas. Students who initially had difficulty in understanding the concept of atomic structure and electron configuration can now connect various types of representations better. Macroscopic representations help them understand phenomena that can be observed directly, submicroscopic representations help them imagine atomic structures that cannot be seen with the naked eye, while symbolic representations help them interpret and apply these concepts in solving chemistry problems. The results of this study have broad implications in the development of chemistry learning strategies, especially for students in areas that have limited access to adequate learning resources. Multiple representation-based scaffolding can be an effective solution in bridging the gap in students' understanding of abstract concepts, especially for those with low numeracy skills. Therefore, this approach can be an alternative for teachers in developing more inclusive learning methods that are appropriate to the needs of students in various educational settings. In addition, the results of this study also show that scaffolding-based interventions can increase students' confidence in understanding concepts that they previously considered difficult. With gradual support in learning, students feel more confident in answering questions and solving problems related to atomic structure and electron configuration. This is in line with Vygotsky's cognitive development theory, which states that learning in the zone of proximal development (ZPD) can be more effective if given appropriate assistance until students are able to learn independently.

Based on these findings, it is suggested that scaffolding-based learning continue to be developed and applied in various other chemistry topics, not only in atomic structure and electron configuration. Further research can be conducted to explore how this strategy can be applied in other chemistry concepts that also have a high level of complexity, such as thermochemistry, chemical equilibrium, and reaction kinetics. Thus, this study not only contributes to improving students' understanding of atomic structure and electron configuration, but also in developing more effective learning methods in chemistry in general. Overall, this study shows that the use of multiple representation-based scaffolding can be an effective approach in improving students' understanding of the concepts of atomic structure and electron configuration, reducing misconceptions, and increasing their learning motivation. With the wider application of this strategy, it is hoped that chemistry education in the 3T areas can become more inclusive and provide better opportunities for students to gain a deeper understanding of chemistry. For further research, it is suggested that further exploration of the effectiveness of multiple representation-based scaffolding in other chemistry materials be carried out as well as a deeper analysis of the factors that can increase the effectiveness of this strategy in learning.

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CONCLUSION

This study aims to analyze the effectiveness of scaffolding-based learning with multiple representations in improving students' understanding of atomic structure and electron configuration. Based on the results of research conducted on 42 students from the 3T area, it was found that this learning strategy had a significant positive impact on conceptual understanding, misconception reduction, and student learning motivation. The results of the pretest and posttest showed a significant increase in conceptual understanding in the experimental group compared to the control group. The average pretest score of the experimental group was 45.2 and increased to 78.5 in the posttest, while the control group increased from 46.1 to 62.3. These data indicate that the scaffolding strategy based on multiple representations is more effective in helping students understand abstract concepts in atomic structure and electron configuration. In addition, this learning strategy has also proven effective in reducing misconceptions that students had before the intervention.

Several misconceptions that were often found before learning, such as the assumption that atoms are solid balls without empty space and electrons move in fixed orbits, decreased significantly after the implementation of scaffolding. Students began to understand the basic concepts of modern atomic theory better after being given learning based on macroscopic, submicroscopic, and symbolic representations. From the aspect of learning motivation, the results of interviews and questionnaires showed that students who took scaffolding-based learning were more motivated and confident in understanding the material on atomic structure and electron configuration. This approach helped them connect theory with real representations, thus increasing their interest in learning chemistry. Thus, this study concluded that scaffolding-based learning with multiple representations is an effective strategy in improving students' understanding, reducing misconceptions, and increasing learning motivation on the material on atomic structure and electron configuration. This strategy is recommended to be applied more widely in chemistry learning, especially for students in 3T areas who have limited access to learning resources and low numeracy skills. As a follow-up, further research can be conducted to explore the effectiveness of this strategy in other chemistry topics, such as thermochemistry, chemical equilibrium, and reaction kinetics. In addition, the development of scaffolding-based learning materials with a digital technology approach can also be an innovative step to increase the accessibility and effectiveness of learning in various educational contexts.

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