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Implementation of IMWR (Inspiring-Modeling-Writing-Reporting) scaffolding on students' cognitive learning outcome in the stoichiometry topic

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Abstract: Stoichiometry is one of the essential chemistry topics that is an abstract concept, involves complex calculations, and is related to other chemical concepts. It can cause not a few students to have difficulty learning it. Scaffolding is needed in the learning process of stoichiometry concepts to help students understand concepts more easily and improve learning outcomes. This research aims to determine differences in students' cognitive learning outcomes on the stoichiometry topic after implementing the IMWR scaffolding model. This research used experimental research with the one-group pretest-postest design. Respondents were 32 high school students who were determined by purposive sampling. The instrument test consisted of 32 items of essays that were valid and reliable. Data is collected and carried out through pretest and posttest. The differences in students' cognitive learning outcomes were analyzed descriptively using the N-gain test and statistical analysis using the paired sample t-test. The paired sample t-test showed a significance value of 0.000 (sig. <0.05), meaning there were differences in student learning outcomes after implementing the IMWR Scaffolding learning model. However, the resulting difference is not significant and is in a low category (N-gain 0.27). Implementing IMWR scaffolding needs to be designed as best as possible by paying attention to students' character to help students understand the concept using procedural knowledge, which impacts better learning outcomes.

Keywords: Scaffolding, IMWR, stoichiometry, inspiring, modeling, writing, reporting

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INTRODUCTION

The learning process significantly influences the ability and success to achieve graduate competence (Kemendikbud, 2013). Chemistry is one of the subjects taught in high school that studies matter and its properties, natural and experimental changes in matter, and the structure and energy accompanying changes in matter (Jespersen, Brady, & Hyslop, 2012). Students often think that chemistry is difficult to understand because it is abstract and its concepts are interrelated (Agustin et al, 2018). Understanding one concept will affect the understanding of other concepts, so each must be mastered correctly (Widiyanti & Saptorini, 2014; Sa'adah, et al, 2020). Stoichiometry is one of the basic concepts in chemistry related to many other chemical concepts.

Stoichiometry is one of the materials studied by class X high school students. Stoichiometry studies quantitative relationships involving atomic mass and formula mass, chemical formulas, and chemical equations (Jespersen et al., 2012). Stoichiometric characteristics include concepts, laws, and basic chemical calculation formulas (Devi et al., 2014) requiring qualified mathematical and problem-solving abilities. Besides that, understanding stoichiometry also requires a conceptual understanding of various other concepts, such as the particulate nature of matter, moles, Avogadro's number, equalization of chemical equations, the law of fixed and multiple comparisons (Sunday et al, 2019; Etokeren, Ibemenji, & Alamina, 2019; Jespersen et al., 2012). High school learning generally emphasizes problem-solving techniques based on calculations and a little conceptual understanding. Even though in stoichiometry material, students are not only required to be able to complete chemical calculations, but students must also connect the basic concepts that have been obtained before and apply them to chemical calculation concepts. The difficulty in understanding stoichiometry lies in the complexity of performing calculations and the low level of understanding of the concept. A low understanding of stoichiometry will cause difficulties in further materials related to stoichiometry, such as electrolysis, calculation of buffer solutions, hydrolysis, and others (Hanson, 2016). These difficulties can lead to low student activity and motivation in learning. One example is the need for more desire of students to ask questions and respond to problems given in learning. Low student activity and motivation during the learning process will affect low understanding (Slameto, 2003). Activeness and student learning motivation can be improved by applying a suitable learning model that fits the student's criteria. One learning model that is expected to increase student activity and motivation and foster a positive impact on student learning outcomes is IMWR scaffolding.

IMWR scaffolding is a learning model that applies problem-solving techniques that emphasize procedural knowledge assisted by tutors with higher knowledge of the inspiring, modeling, writing, and reporting stages (Sari, 2017). The inspiring stage provides support that initiates and fosters students' curiosity and brings students to think (Wakhidah et al, 2016). Students who can connect the initial concept and the concept to be studied can write it (writing) directly and communicate (reporting). In contrast, students who cannot connect the initial concept and the concept to be studied need to be given an example (modeling) of how to observe something phenomena correctly, formulate problems, design experiments/observations in order to solve problems, analyze experimental results, and communicate experimental results (Wakhidah et al, 2016). The assistance provided aims to reduce complexity, get directions, and make it easier for students to complete their assignments (Morgan & Brooks, 2012).

The characteristics of IMWR scaffolding described above are expected to increase student learning activity and motivation. Increasing student activity and motivation is expected to impact improving student chemistry learning outcomes positively. Previous research reported that implementing IMWR scaffolding impacted science process skills and students' mastery of concepts in science learning (Wakhidah et al, 2016), and improved learning outcomes (Ayu, 2017IMWR scaffolding has yet to be widely applied in chemistry learning, especially for stoichiometry topics. IMWR scaffolding in chemistry learning has been applied to hydrocarbon material. However, the results still need to be more effective in improving student learning outcomes (Nabila, 2017) because the scaffolding treatment is inappropriate and does not under student character and concepts. Based on this, it is important to implement IMWR scaffolding on the concept of stoichiometry on student learning outcomes. Assistance is packaged in the form of lesson plans and worksheets that are adapted to student characteristics and the concept of stoichiometry. The IMWR assistance is designed to build feedback between students and students and students and teachers during the learning process so that social interaction, information exchange, debate, and discussion between students occur, which can motivate one another to solve a problem that is difficult to solve individually. In its implementation, the four stages of IMWR (Inspiring-Modelling-Writing-Reporting) assistance are expected to increase students' curiosity, help connect prior knowledge with new knowledge, and help students focus their attention on the topic of discussion. The research question is how the differences in students' cognitive learning outcomes before and after implementing IMWR scaffolding on stoichiometry material.

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METHOD

Research Design

This research is experimental with The One Group Pretest-Postest Design adapted from Fraenkel, Wallen, & Hyun (2011). The research design is presented in Table 1. This study involved 32 students of class X MIA from a high school in Serang Regency.

Table 1. *One Group Pretest-Posttest Research Design*

Pretest (O)	Treatment	Posttest (O)
O_1	X	O_2

Ketarangan: O_1 : pretest*;* X : treatment of the IMWR scaffolding model in the experimental class; and O_2 : posttest (Fraenkel et al., 2011).

Sampling and Samples

As many as 32 class X students in one of the senior high schools in Serang Regency, Banten, were involved in this research. The sampling technique was carried out using a purposive sampling technique because, in this study, the samples used had specific characteristics according to the research objectives.

Instruments and Data Collection Techniques

The test instrument used to measure student learning outcomes on stoichiometric material is in the form of description questions which consist of 32 item questions. The 32 questions were developed based on six learning indicators on the concept of stoichiometry material. The test instrument was first validated by the contents involving nine experts in the field of chemistry education and then analyzed using the Content Validity Ratio (CVR) test. Each test item is considered valid if it has a CVR value above the minimum value for nine validators, namely 0.78 (Cohen & Swerdlik, 2018). Based on the results of the CVR calculation, the CVR value was 1.0 for 12 questions and 0.78 for the other 20 questions. These results indicate that 32 test items are valid (CVR value ≥ 0.78) and appropriate for this study's use. The reliability test was taken from the results of empirical tests on 30 students and analyzed with SPSS. The reliability test results showed that the 32 questions tested each had a Cronbach's alpha value of 0.75 ($r11 > r$ table or $0.75 > 0.355$), meaning that the items tested were reliable and had a high level of reliability.

Data analysis

Research data analysis techniques consist of statistical analysis and descriptive analysis. Statistical analysis was conducted to test the research hypothesis regarding whether there were differences in student learning outcomes in applying IMWR scaffolding. Hypothesis testing was done through a paired sample t-test with a sig of 5%. A prerequisite test, namely the data normality test, is carried out before testing the hypothesis. The normality test results were carried out using the Kolmogorov-Smirnov method with a significance level of 0.05. The normality test results showed that the significance of the pretest and posttest were 0.067 and 0.057, respectively, so it could be concluded that the sample had a normal distribution. The descriptive analysis explains and analyzes differences in student learning outcomes in the application of IMWR scaffolding. Descriptive analysis is based on the results of the N-Gain test from pretest-posttest values..

Treatment Procedure with IMWR

Implementation of the IMWR scaffolding learning model in this study was carried out through stages adapted from Mamin (2008). The stages in this study are presented in Figure 1.

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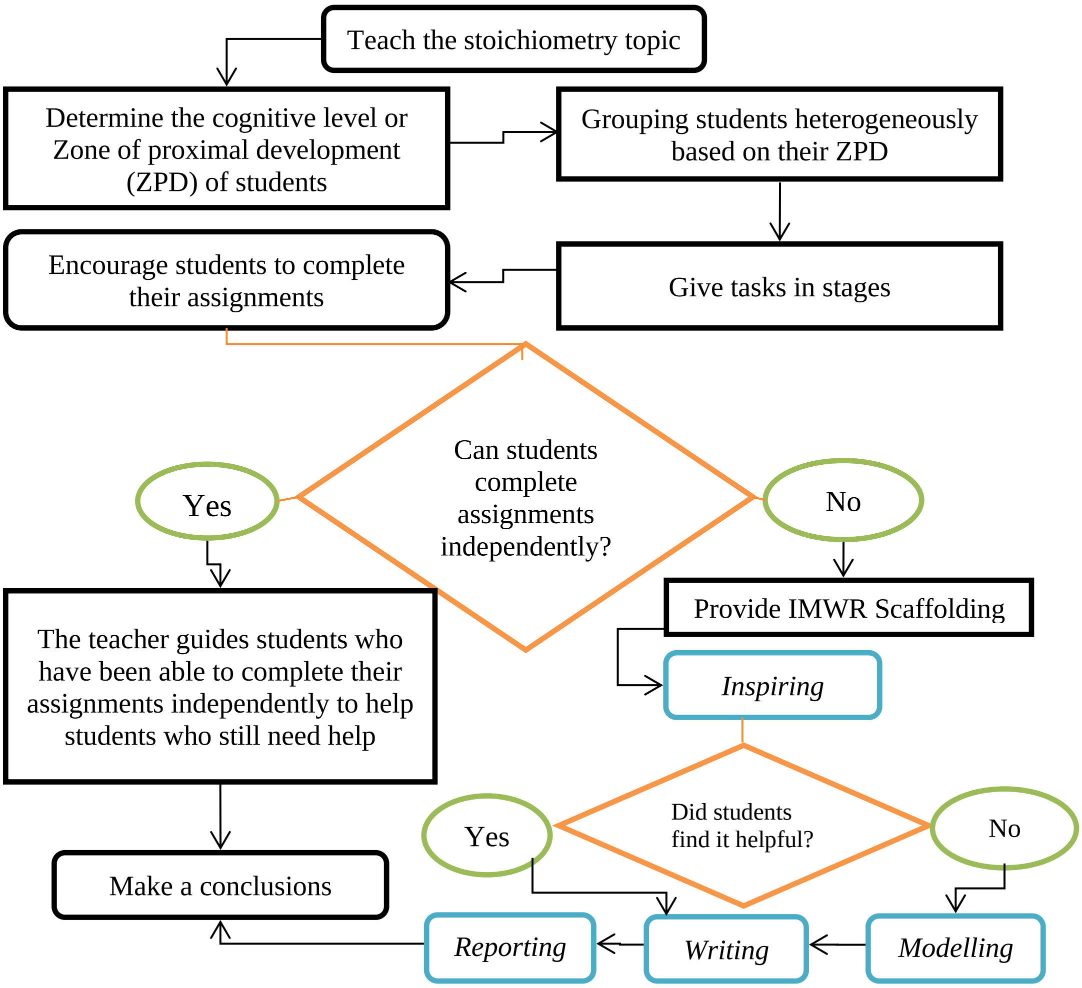

Figure 1. Steps of IMWR Scaffolding Learning Model

RESULTS AND DISCUSSION

This research was conducted to determine differences in student learning outcomes before and after applying IMWR scaffolding (Inspiring-Modeling-Writing-Reporting) on stoichiometry material. The four types of assistance used in this study were provided in stages inspiring, modeling, and writing to reporting (Wakhidah et al, 2016). These four aids are illustrated in the LKS. LKS is used in order to make the learning process more effective. In addition, the LKS is part of the student assignments that the teacher has prepared. The application of scaffolding requires assignments prepared by the teacher so that scaffolding can run effectively (Nusu, 2014). Assisting in the learning process is well designed with the hope that it will be effective and positively impact student learning outcomes.

Students' cognitive learning outcomes on implementing the IMWR scaffolding model were measured through pretest and posttest. The difference in the average pretest and posttest scores is presented in Figure 2. Students' cognitive learning outcomes in the stoichiometry material increased from an average score of 2.875 to 29.563. The difference in learning outcomes is also shown by the results of the paired sample t-test (Table 3). The results of the paired sample t-test show the sig. 0.000 (Ho rejected), which means there is a difference in the average value before and after implementing the IMWR scaffolding model on stoichiometric material. However, the increase was insignificant, as indicated by the N-gain value of student learning outcomes which was still relatively low at 0.27. The low increase in student learning outcomes can be analyzed from the four types of assistance implemented during the learning

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process. The assistance provided at the inspiring, modeling, writing, and reporting stages could have been more optimal due to several factors, which will be described at each stage below..

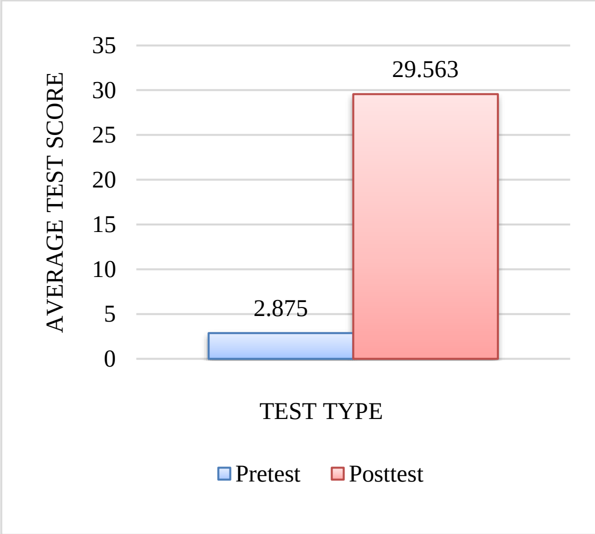

Figure 2. Graph of Average Pretest and Posttest Scores

Table 3. Paired Sample T-Test Results

t	*df*	*Sig. (2-tailed)*	Decision
-17.069	31	0.000	H_o is rejected

Inspiring

The assistance provided at this stage begins by exploring students' prior knowledge. The initial knowledge needed in studying stoichiometry is the fundamental laws of chemistry and the mole concept. Both of these materials are the basis of material for chemical reactions and calculations (Niaz & Montes, 2012). At the inspiring stage, teachers and students can inspire by associating prior knowledge, fostering curiosity, and encouraging students to think and do their assignments independently (Purnamasari, 2017). This is in line with Vygotsky's learning theory which states that learning is also a process of assimilating and connecting the experience or material being studied with the understanding that someone already has so that understanding can be developed (Andarini, Masykuri, & Sudarisman, 2013). Inspiring is done by briefly conveying material on the fundamental laws of chemistry and the relationship between the concept of moles and chemical calculations so that students can remember and relate their initial knowledge to the new knowledge being learned. Observations during the Inspiring stage revealed that students' initial knowledge still needed to be improved. Students' initial knowledge regarding the basic laws of chemistry and the mole concept is inadequate, so this stage is not optimal. Stoichiometry is a chemistry topic that requires more conceptual understanding; students need help understanding the initial concept to learn this material (Shadreck & Ochonogor, 2018). The inspiring stage can run optimally if students have an adequate provision regarding initial knowledge related to the new knowledge to be learned so that students can develop their knowledge easily. Initial knowledge can also help students learn well on higher material or concepts (Astuti, 2015). The development of learning outcomes observed at this stage is that the treatment can arouse students' curiosity and lead students to think further about stoichiometry.

Modelling

If assistance through the inspiring stage is deemed insufficient for students to generate motivation and focus on learning, the assistance needed is modeling. Modeling is important to

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make a concept easy to understand and increase students' curiosity so that students will be more motivated to learn (Rusman, 2012). In this study, modeling was carried out by providing examples of writing reaction equations and their equivalents and examples of completing tasks in the form of calculations based on balanced reaction equations, all summarized in worksheets. When given modeling regarding the determination of reaction equations and chemical calculations, students still need to understand modeling regarding chemical calculation material. That can be seen when students are given assignments regarding chemical calculations in worksheets; students cannot answer these tasks correctly. Likewise, with modeling for limiting reactants, students need help understanding it. The lack of optimal modeling application in the learning process resulted in students needing help understanding the material and answering chemical calculation questions, so they were still not quite right in answering assignments on worksheets and posttests. Modeling should be done through examples and using pictures, animations, or analogies that can better represent abstract concepts. The modeling stage can run optimally if the teacher is more careful in paying attention to student readiness, such as material that supports student understanding (initial knowledge) and students' algorithm abilities in understanding chemical calculation material (Rahmawati, 2019).

Writing

After the modeling stage, students are directed to the third stage, namely writing. In principle, writing is done so that students can focus their knowledge and answer assignments in the form of questions correctly. In addition, writing can also be used as a benchmark for researchers regarding the level of students' understanding in written form before students present the results of their assignments orally (Tarigan, 2008). Students in groups write down the results of observations from modeling in worksheets. The LKS presents questions that direct students to write down their understanding after being given the inspiring and modeling stage. Based on students' answers on LKS, students still need to understand the use of formulas to complete tasks in chemical calculations. In the learning process, students are not first provided with material on the basic laws of chemistry and the concept of moles, so this makes it difficult to do calculations.

Reporting

At this stage, students perform by conveying their findings in completing assignments based on their understanding. At this stage, students can present the results of their understanding well based on the presentation points written on the LKS. Reporting can help students determine the right or wrong concepts they have. During the reporting stage, the teacher corrects students' inappropriate understanding, provides reinforcement of material and concepts considered important, and guides students to make conclusions from learning (Juniati, 2017). Learning progress that can be observed from the reporting stage is that students are actively involved in discussion activities and can make conclusions from what has been learned.

Based on the results of the post-test answer analysis, students still had difficulty in (1) determining the moles, masses, and volumes of reactants and reaction products based on the reaction equation; (2) proving the moles, masses, and volumes of reactants and reaction products based on the reaction equation; and (3) determine the limiting reagent and excess reagent based on the data provided. It happened because IMWR assistance could have been more optimal given to students, as previously explained. In addition, this also occurs because the LKS being used cannot make students find their knowledge and complete their assignments independently. LKS in the section on inspiring and modeling that is applied in the learning process could be more suitable and understood by students, even though based modeling theory significantly contributes to building students' problem-solving abilities (Ozdemir & Uzel, 2014). These results are the same as previous research using worksheets and modeling as an aid in applying scaffolding, which shows that scaffolding does not significantly improve student

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learning outcomes (Nabila, Gani, & Habibati, 2017). The modeling assistance contained in the LKS only provides an example of completing tasks related to the discussion material provided, so it is necessary to provide another modeling, such as mathematical modeling or other forms of modeling. LKS must also be equipped with case studies on the concepts being studied to train students' problem-solving skills.

The analysis results also show another factor that is the reason for the low increase in students' cognitive learning outcomes in stoichiometric material, namely the need for students' algorithm skills in solving calculation problems. Algorithmic ability is one factor that influences chemistry learning outcomes; the higher the level of algorithm ability, the higher the chemistry learning outcomes that will be achieved (Adigwe, 2013). Algorithm capabilities can improve chemical problem-solving abilities and positive attitudes toward chemistry (Merdekawati, 2013). Explanation of stoichiometry material cannot be appropriately understood if students' algorithmic abilities are still low and there is no prior knowledge that builds students' understanding of the material. That is because stoichiometry is a chemical material that requires a conceptual understanding of various other concepts, such as the particulate nature of matter, moles, Avogadro's number, equalization of chemical equations, the law of fixed and multiple comparisons (Sunday *et al*, 2019).

The IMWR scaffolding learning model emphasizes procedural knowledge that links the provision of support or assistance to students by teachers or students who can better understand the topic with the inspiring, modeling, writing, and reporting stages (Amanah, Harjono, & Gunada, 2017). Students have two development zones, namely actual development, which can be interpreted as the ability to solve problems independently, and potential development, which is the ability of students to solve problems by needing help (Morgan & Brooks, 2012). The distance between the actual level of development and potential development is called the Zone of Proximal Development or ZPD. This zone is a potential for student development when assistance is given (Morgan & Brooks, 2012). In this study, the provision of assistance was adjusted to the student's ZPD level and the student's needs to understand the concepts being taught to complete the assignments. Assisting in the learning process aims to enable students to achieve their ZPD.

In the learning process, students are formed into five small groups heterogeneously based on their ZPD level, determined by the pretest scores. The formation of a heterogeneous group aims to motivate students who are at low ZPD in learning due to the provision of assistance from other students who are more capable of completing assignments (Minanti *et al*, 2016). In addition, students who have good abilities tend to be faster in completing assigned tasks (Khasanah, 2012). Heterogeneous group formation is expected to efficiently use time in completing tasks that do not require a long time, and learning runs effectively. However, even though scaffolding can improve the quality of learning (Ayu, Pratiwi, Kusairi, & Muhardjito, 2017), the formation of heterogeneous groups makes it difficult for researchers to know the level of understanding and the type of assistance needed by students who are at a low ZPD level due to tasks that are given in the form of worksheets are done mainly by students who are at a high ZPD level.

CONCLUSION

The analysis results show differences in students' cognitive learning outcomes in the application of learning with IMWR scaffolding. Learning with IMWR scaffolding positively impacts student learning outcomes, although not significant (N-gain 0.27). The results of further analysis during the learning process found that the implementation of IMWR scaffolding needs to be designed as well as possible so that the assistance provided can be in accordance with the student's character. Assisting tutors through the inspiring, modeling, writing, and reporting stages must be able to assist students in solving problems by emphasizing procedural

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knowledge, which impacts better learning outcomes. Several important things need to be considered in implementing the IMWR scaffolding model in the future: (1) the heterogeneous grouping of students based on ZPD levels makes students at low ZPD levels less active, (2) prior knowledge and algorithm skills are needed to understand stoichiometry material easily, (3) it is necessary to have other forms of modeling, such as using mathematical sentences, symbols, or molecular symbols of compounds, so that the modeling provided can help make it easier for students to understand the material, (4) this study only used a sample of one class, so it is necessary to conduct research using samples of two classes in order to see differences in the increase in student learning outcomes and the magnitude of the effect of using the IMWR scaffolding model with the use of learning models other than IMWR scaffolding.

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