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The Effectiveness of the EIGER Learning Strategy in Promoting Students' Conceptual and Algorithmic Understanding of Stoichiometry

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This research sought to examine the effect of the EIGER learning strategy on senior high school students' conceptual and algorithmic understanding in topics of stoichiometry. The research used a quasi-experimental method with a pretest-posttest control group design. The research subjects were selected by simple random sampling technique, consisting of two classes of grade 10 out of three existing classes. The experiment class was taught with the EIGER (Engage, Investigation, Guided-connection, Evaluation and Reflection) instructional strategy, and the control class was taught with the verification learning strategy. The research instrument used paired test with multiple-choice items (r = 0.93) to measure conceptual and algorithmic understanding in topics of stoichiometry. The research data were analyzed using descriptive and inferential statistics. The results of the research showed that the EIGER learning strategy had a more significant effect on students' conceptual and algorithmic understanding than the verification learning strategy. The N-gain score for EIGER class students' conceptual understanding indicated high effectiveness (N-gain = 0.73) and algorithmic understanding indicated high effectiveness (N-gain = 0.76), while the N-gain score for verification class students' conceptual understanding indicated moderate effectiveness (N-gain = 0.52) and algorithmic understanding indicated moderate effectiveness (N-gain = 0.60). This research's implication for teachers is that the EIGER learning strategy can be used to enable students to apply not only their algorithmic understanding but also their conceptual understanding.

Keywords: algorithmic understanding, conceptual understanding, EIGER learning strategy, stoichiometry, learning

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INTRODUCTION

Chemists usually explain chemistry at three different levels of representation: macroscopic, sub-microscopic, and symbolic (Treagust et al., 2003). Macroscopic representation is tangible (what can be seen, touched, and smelt) (Johnstone, 2000). An instance for this level of representation is the white deposit of AgCl being formed from the reaction between NaCl and $AgNO_3$ solution. Sub-microscopic representation is an abstract level that explains materials and chemical processes in their particulate forms (e.g., atoms, molecules, ions, and structures) (Johnstone, 2000; Sunyono, 2015; Talanquer, 2011). An instance is the sub-microscopic representation of a reaction in which the white deposit of AgCl is formed through collisions of ions, especially between Ag^+ and Cl^- ions. Symbolic representation, meanwhile, is the representation of concrete phenomena in the form of formula, equations, mathematical manipulations, or graphs (Johnstone, 2000). An example of the symbolic representation of a reaction is the equation of the reaction $AgNO_3(aq) + AgCl(aq) \rightarrow NaNO_3(aq) + AgCl(s)$. The three levels of representation above mentioned are interconnected and contribute greatly to students in building definitions and conceptual understanding (Ahmar et al., 2020; Johnstone, 1991). If students understand the roles of the three levels of representation above, it is expected that they can transfer their knowledge by making a connection of those three levels of representation. This indicates that they have gained the conceptual understanding needed to solve problems (Sunyono, 2015). For example, students are able to solve a problem by calculating the quantity of the AgCl deposit produced. The calculation of the quantity of AgCl deposit based on the number of reactants used involves a series of chemical calculations called stoichiometry. To solve this problem, students must have correct conceptual and algorithmic understandings.

Research results show that most students have difficulties in understanding chemical concepts (Nakhleh, 1992; Stamovlasis et al., 2005; Tarkin & Uzuntiryaki-Kondakci, 2017). Students' conceptual understanding is still in the form of conceptual fragments that are isolated from one another, and students are yet to be able to connect such concepts correctly (Nehru et al., 2020). The majority of students are only able to solve problems using algorithmic methods (Cracolice et al., 2008; Gabel et al., 1984; Nuzulia et al., 2018; Schmidt, 1994). Many teachers believe that teaching students to solve problem algorithmically is equal to teaching concepts (Nuzulia et al., 2018; Niaz, 1995), so they assume that being able to solve algorithmic problems is the same as being able to understand concepts. A case in point is that students can solve problems on gas without knowing many things about the properties of gas and they can work on limiting reaction problems without the understanding of the nature of chemical changes (Cracolice et al., 2008; Nurrenbem & Pickering, 1987). According to Dahsah & Coll (2008), chemical instructions that are only algorithmically focused will generate a shallow understanding, as in teaching the concept of the mole with a focus on memorizing the mole diagram and mole conversion exercises. Although it is effective in teaching algorithmic methods to students for them to calculate molar quantities, this approach theoretically makes it difficult for students to understand the actual concept of the mole. It is the very thing that makes students tend to consider chemical concepts abstract and confusing, hence often causing misconceptions that are hard to overcome

(Wakeley & De Grys, 2000). The reason why beginning students experience difficulties in building conceptual understanding is that they tend to construct explanations based on surface features. For example, when asked “which one between 20 g of neon and 40 g of calcium has a greater number of atoms?”, students will commonly answer that 40 g of calcium has more atoms than 20 g of neon, and when they are asked to identify the atom mass, they will typically use the molar mass of the element (Chi et al., 1981; Chi et al., 1994; Horsch & Burnett, 1995; Kuhn, 2011). The difficulties in building a conceptual understanding make most students feel that chemistry is a difficult subject (BouJaoude & Barakat, 2003; Cervellati et al, 1982; Wood & Breyfogle, 2006). Their weaknesses in conceptual understanding will make them unable to use concepts to solve problems. If they only rely on algorithmic understanding to solve problems, students will fail to make connections and hence find it difficult to understand new concepts (Taber, 2009). This is also experienced by students grade 10 of a senior high school in Pinrang district that based on the data of pre-test, students were able to determine the mass of reacting substance based on the mass of substance after reacting, however they did not understand whether it also applied to all forms of matter or only to substances that were liquid and solid. This should be overcome with an appropriate learning strategy. In this research, a learning strategy is designed to promote students’ conceptual and algorithmic understanding.

Context and Review of Literature

Stoichiometry

Students who are able to represent their algorithmic understanding correctly have a good conceptual understanding (Purwadi et al., 2019). The most fundamental concept in chemistry is stoichiometry (Fach et al., 2007). It involves conversions of chemical formulae and equations that represent atoms, molecules, and units of formulae to the laboratory scale using miligrams, grams, and even kilograms of substances (Jespersen et al., 2012). Materials on stoichiometry are important to understand the quantitative and qualitative aspects of chemical reactions and to solve chemical problems of various types at the senior high school level (BouJaoude & Barakat, 2003; Sunyono, 2015). Stoichiometry is a collective term to denote the quantitative relationship between masses, molar numbers, and particle numbers (atoms, molecules, and ions) of the reactants and products in a balanced reaction (Sujak & Daniel, 2017), and atom masses, molar masses, and particle numbers in moles are abstract concepts (Horsch & Burnett, 1995). It requires students to have skills in writing down chemical formulae, tell subscripts apart from coefficients, write down balanced chemical equations, and understand concepts of the mole, molar mass, molar volume, and limiting reactants. Students’ weakness in such skills may cause them to be unable to solve stoichiometric problems (Glažar & Devetak, 2002; Sanger, 2005).

Stoichiometry involves both conceptual and algorithmic understanding (Kimberlin & Yezierski, 2016). The former is an ability to apply knowledge in various instances and situations, and this basic ability is a must for every student. Students who are unable to understand basic concepts correctly may have low conceptual understanding (Ellis, 2013; Lestari et al., 2019; Putranta & Supahar, 2019). Meanwhile, the latter is understanding in relation to mathematic calculations. It requires the understanding of a series of problem-solving procedures, including the use of mathematical formulae, making it imperative for students to have the ability to think proportionally (Nakhleh & Mitchell, 1993; Tingle & Good, 1990; Nuzulia et al., 2018). For instance, the concept of limiting reactant refers to a reactant that is completely consumed when a reaction is completed, while a reactant with an excess is called an excess reactant. With a correct conceptual understanding of limiting reactants, students will be able to differentiate between limiting reactants and excess reactants. Using their algorithmic understanding of the determination of molar mass and molar number, students will be able to determine how many grams of a limiting reactant is left when a reaction is completed and how many grams of a compound is obtained.

An Instructional Strategy to Promote Conceptual and Algorithmic Understanding

Many students are able to apply algorithmic understanding without a significant conceptual understanding, and teachers believe that teaching students to solve algorithmic problems is equal to teaching them concepts. However, such a belief is far from the truth (Nuzulia et al., 2018; Cracolice et al., 2008; Niaz, 1995; Pushkin, 1998). It thus becomes necessary to think of what strategy to apply in order for students to be able to not only solve algorithmic problems, but also understand the underlying concepts. Algorithmic problem-solving abilities are not too helpful when it comes to honing conceptual problem-solving abilities. On the other hand, conceptual problem-solving abilities are capable of facilitating algorithmic problem-solving (Niaz, 1995). Students' conceptual and algorithmic understanding can be improved by giving students more opportunities to demonstrate both their conceptual and algorithmic understanding (Pushkin, 1998). Nonetheles, with the learning strategy they have over the time implemented, teachers hardly ever complained about students' algorithmic understanding; most teachers reported that students' conceptual understanding was low (Nakhleh & Mitchell, 1993; Stamovlasis et al., 2005). Therefore, it is critical to design a learning strategy that can improve students' conceptual understanding.

Research results show that conceptual understanding can be enhanced through the implementation of appropriate learning strategies. A learning strategy that is effective to improve students' conceptual understanding is the inquiry-based learning strategy (Artayasa et al., 2018; İncikabi, 2014). Inquiry activities require sound preexisting knowledge on the students' part and facilitation for students with less preexisting knowledge (Gunawan et al., 2020). In inquiry-based instructions, students are highly enthusiastic, and when they find difficulties, they will ask their teacher right away. Every stage in inquiry-based instructions can encourage students' metacognitive activities, especially when they engage in group discussions (Hastuti et al., 2020). Inquiry-based instructions are by Marek termed LC-3E. The three-phase learning cycle (LC-3E) is exploration, concept development (explanation), and expansion derived from Piaget's model of mental functions (assimilation, disequilibration, accommodation, and organization). In the exploration stage, students assimilate the data presented in order to bring about dis-equilibration. The second stage is explanation, designed to guide students through the process of data interpretation, concept construction, and accommodation to produce re-equilibration. The third stage, elaboration, is designed to give an opportunity to students to organize the newly received concept with the concepts they have already been aware of (Marek, 2008). This inquiry-based instruction model was further advanced by Bybee et al., (2006) into the LC-5E model, which is comprised of five stages of engagement, exploration, explanation, elaboration, and evaluation. According to Pedaste et al. (2015), inquiry-based instructions provide students with opportunities to find ideas in concepts building based on the concepts they have previously mastered. Inquiry-based instructions such as the LC-5E model are constructivist instructions that encourage students to learn actively, improve their conceptual understanding, and give them a better understanding of scientific knowledge, technology, attitude, and learning (Abraham & Renner, 1986; Bybee et al., 2006; Supasorn et al., 2014; Temel et al., 2013).

Studies concerning conceptual understanding and algorithmic understanding separately have been many (Costu, 2010; Coştu, 2007; Holme & Murphy, 2011; Mason et al., 1997; Nakhleh & Mitchell, 1993; Niaz & Robinson, 1992, 1993; Perrenet et al., 2005; Salta & Tzougraki, 2010; Slesnick, 1982; Stamovlasis et al., 2005). However, adapting an inquiry learning strategy such as LC-5E with the addition of a concept validation stage at the end of the investigation stage in the EIGER (Engage, Investigation, Guided-connection, Evaluation and Reflection) learning strategy aimed at enhancing conceptual and algorithmic understanding simultaneously have not been reported. Based on the findings of those studies, instructions that can improve conceptual understanding and algorithmic understanding should meet the following criteria. *Firstly*, the instructions are commenced with accessing students' preexisting knowledge and assisting them in engaging in new concepts. This is because new knowledge attaches better when students have mastered well- and correctly-understood prerequisite concepts (Ambrose et al., 2010). *Secondly*, the instructions stress how students can find concepts. Instructions with an emphasis on conceptual understanding are more effective in algorithmic problem-solving (Gultepe et al., 2013). *Thirdly*, the instructions must engage students in problems to know the extent of their understanding of the materials they are learning. As stated by Lawson et al. (1995), if students are not engaged in problem-solving, then their understanding will be limited to the examples given by the teacher. *Fourthly*, the instructions are wrapped up with evaluation and reflection. Evaluation is conducted to find out whether the teacher's teaching method is effective. For the students, evaluation is useful to find out to what extent they understand the learning materials and whom among them need more aid to improve their understanding (Arends & Kilcher, 2010; Slavin, 2006). Meanwhile, reflection in instructions is performed to avoid misunderstanding as students are often inaccurate in drawing conclusions based on the information that they have gained in the learning process (Andrews & Brown, 2009).

The four criteria, when integrated, will generate a learning strategy presumably effective in improving students' conceptual and algorithmic understanding. These criteria have similarities with the inquiry learning stage. Therefore, the researchers developed a learning strategy adapting the stages in inquiry-based instruction. However, the implementation of inquiry-based instructions, both under the LC-3E and the LC-5E models, is not explicit in demonstrating activities of understanding reinforcement or conceptual validation against preexisting concepts. It is known that conceptual validation is vital in the learning process and in students' conceptual understanding. According to Effendy (2002), conceptual validation seeks to figure out whether the understanding that is formed in students' mind is compatible with scientific understanding. Such a gap in inquiry-based instructions is filled by adding the activity of conceptual understanding reinforcement or conceptual validation in the investigation stage of the EIGER learning strategy. This activity is intended to find out whether the understanding that is formed in students' minds is in accordance with the actual concepts. Therefore, the researchers developed this learning strategy named EIGER by adapting the stages in LC-3E and LC-5E learning, which consists of four stages of engagement, investigation, guided connection, and evaluation and reflection.

The EIGER learning strategy is a constructivist learning strategy. Constructivist instructions position students as the centers of learning who actively construct understanding on their own (Treagust & Duit, 2009). Constructivist learning according to José et al., (2020) is a construction in which the structure of the mind is modified, so as to achieve greater diversity, complexity, and integration, each new restructuring which implies a return to the spiral of knowledge. In the implementation of the EIGER learning strategy, students are not only guided to construct a concept, but also engaged in algorithmic problem-solving, so the teacher will know the extent of the students' understanding. Therefore, it was deemed necessary to conduct a study to figure out the effect of EIGER strategy implementation on students' conceptual and algorithmic understanding.

Research Question

This research aimed to examine the effect of the EIGER learning strategy on students' conceptual and algorithmic understanding by comparing students' learning outcomes under the EIGER learning strategy against those under the verification learning strategy.

The research questions are formulated as follows:

1. Is there any difference in conceptual understanding between students instructed using the EIGER learning strategy and those instructed using the verification learning strategy in topics of stoichiometry?
2. Is there any difference in algorithmic understanding between students instructed using the EIGER learning strategy and those instructed using the verification learning strategy in topics of stoichiometry?

METHOD

Research Design

This research used a quasi-experimental method with a pretest-posttest control group design as described in Table 1.

Table 1
Quasi-experimental research method

Group	Pretest	Treatment	Posttest
E	O	X	O
C	O	-	O

(Creswell, 2012)

E : Experiment group
C : Control group
O : Conceptual and algorithmic understanding test
X : Treatment in the control group (EIGER learning strategy)
- : No treatment in the control group (verification strategy)

Research Subjects

The subjects of this research were students of grade 10 of public senior high school Pinrang. The available curriculum was the curriculum applicable in the Indonesian Education System, namely 2013 Curriculum. The sample was selected by simple random sampling technique. The population consisted of three classes with 100 students, two classes were selected consisting of 64 students grade 10 in the school. Based on the pretest scores, both classes had the same initial abilities (see Table 5 and Table 6). One class of 30 students was assigned as control class and taught with the verification learning strategy and another class of 34 students was assigned as experiment class and taught with the EIGER learning strategy. For assignments, each group was given the same task and each student collected his work at the end of the lesson. This was done to prevent students from exchanging answers to other classes.

Procedure

Before the start of this research, all the research instruments, including tests, instructional scenarios, and teaching materials, were validated by 3 validators. The researchers acquired an official permit from the Education Service of the Pinrang Regency to conduct a study at the school concerned. All the students agreed to participate in this research voluntarily. Regarding confidentiality matters, all the students and teachers were informed that their names were not reported anywhere, and the accessible data were only to be seen by the researchers. The research process was conducted within five months. Two chemistry teachers voluntarily involved in this study and taught students face-to-face over 10 meetings. The experiment and control groups were taught by different teachers. Before the class started, the chemistry teachers were coached how to use the provided teaching materials. In each meeting, the students were taught for 3 contact hours (3 × 45 minutes). In the first meeting, the students were given a pretest to figure out their initial abilities. Based on the pretest results, the two classes had the same initial abilities, so one class was then taught with the EIGER strategy and another with the verification strategy. In the second to the eighth meetings, the students were taught materials on stoichiometry using each predetermined learning strategy. In the tenth meeting, the students were given a posttest to figure out their level of understanding. The verification learning strategy was applied in three stages, namely explanation, verification, and conclusion (Pavelich & Abraham, 1979; Pratiwi, 2015).

Verification instructions per se are instructions that are teacher-centered, while the EIGER learning strategy used in this research is a result of a literature review from a variety of learning strategies that can improve students' conceptual and algorithmic understanding. The stages in the EIGER learning strategy are described in Table 2.

Table 2
Description of EIGER learning strategy implementation

Stage	Description	Student's Activity	Student's Goals
Engagement	This step aims to access prerequisite concepts and students' initial abilities related to stoichiometry. The learning theories underlying the engagement stage are Piaget's cognitive theory and Ausubel's meaningful learning theory. At this stage there is a transfer of knowledge from preexisting concepts to new concepts which are related.	1. Students are divided into heterogeneous groups. 2. Students prepare references which are related to the topic to be studied. 3. Students answer the question from the teacher to access prerequisite knowledge and initial abilities related to the material to be studied. 4. Unify understanding	1. To investigate what students understood and what they did not. 2. To assimilate and accommodate previous concepts with new concepts.
Investigation	This step aims to build students' conceptual understanding. The learning theories that underlie the investigation stage are the theory of constructivism and Vygotsky's social learning theory, where students are social creatures who can construct their own understanding.	1. Students answer questions from the teacher. 2. Students search for explanations. 3. Examine students' explanations 4. Understand the concepts formed by students 5. Students and the teacher validate the concepts to avoid misunderstanding of the concepts that have been studied.	To build students' conceptual understanding and algorithmic understanding
Guided-Connection	This step aims to connect students' algorithmic understanding to their conceptual understanding that has been awakened during the investigation phase. The learning theories that underlie the guided-connection stage are the theory of transfer learning and Thorndike's connectionism theory which says that learning is a relationship between stimulus and response.	Students solve the problems given by the teacher according to the concepts that they have understood.	To apply the concepts that have been built to solve algorithmic problems
Evaluation & Reflection	This step aims to evaluate students' understanding in working on conceptual and algorithmic problems under the same basic topic. Reflection is carried out as a follow-up to the evaluation.	1. Students' understanding is evaluated. 2. Students' understanding is reflected.	To know whether the learning objectives have been achieved or not

Research Instruments

The key component to determine whether students had the right conceptual and algorithmic understanding was to use the paired question format in which comparison of students' performances was taken from the pairs of multiple-choice items designed to provide data on conceptual understanding and algorithmic understanding separately (Costu, 2010; Holme & Murphy, 2011). Students' conceptual understanding and algorithmic understanding in topics of stoichiometry were measured using a multiple-choice paired-test instrument that consisted of researchers-developed 38 pretest and posttest items. The items were stoichiometric problems that were designed in pairs (i.e., in a single topic there were a conceptual problem and an algorithmic problem) according to the learning indicators under the currently applied curriculum in Indonesia, namely Curriculum 2013, and these questions were first validated by 3 experts in chemical education. Based on the validity testing on the items, it was found that all the items were valid ($p < 0.05$) at a Cronbach's Alpha value of 0.93. Examples of problems to guage conceptual and algorithmic understanding can be seen in Figure 1.

1. A reaction can be called a limiting reaction, if ….
   a. the reaction leaves some excess after the reaction is completed, which can be determined based on the number of particles of substances needed to react.
   b. the reaction is completely consumed after the reaction is completed, which can be determined based on the number of moles of substances needed to react.
   c. the reaction leaves some excess after the reaction is completed, which can be determined based on the mass of substances needed to react.
   d. the reaction leaves some excess after the reaction is completed, which can be determined based on the volume of substances needed to react.
   e. the reaction is completely consumed after the reaction is completed, which can be determined based on the phase of the substances needed to react.
2. Lithium oxide (Li_2O) is used on space shuttles to remove moisture in existing air supplies. The reaction is below:

   $$Li_2O(s) + H_2O(g) \longrightarrow 2LiOH(s)$$

   If 8 g of water is to be removed while Li_2O is available at 6 g, then the limiting reactant(s) is/are …. (A_r H = 1; Li = 7; O = 16)
   a. Li_2O
   b. H_2O
   c. LiOH
   d. Li_2O and H_2O
   e. Li_2O and LiOH

Figure 1
Examples of Problems to Gauge Conceptual and Algorithmic Understanding in Topics of Stoichiometry

Data Analysis

The data in this research were gathered based on the pretest and posttest scores both for students' conceptual and algorithmic understanding. A score of 1 was assigned if the answer given by the students was correct and 0 if the answer was wrong. The answers of the students to each item were classified based on the criteria in Table 3.

Table 3
Grouping of student's conceptual understanding and algorithmic understanding

No	Category	Description
1	C1A1	*Correct Conceptual, Correct Algorithmic*
2	C0A1	*Incorrect Conceptual, Correct Algorithmic*
3	C1A0	*Correct Conceptual, Incorrect Algorithmic*
4	C0A0	*Incorrect Conceptual, Incorrect Algorithmic*

(Stamovlasis et al., 2005)

On the whole, the number of students with the same conceptual and algorithmic understanding is shown in graphic percentage (Figure 2). To answer problems 1 and 2, a differential test was carried out with SPSS. To find out the students' scores of conceptual and algorithmic understandings from pretest to posttest, an analysis was carried out using N-gain score. According to Meltzer (2002) and Bao (2006), N-gain score can be calculated using the equation below:

$$\text{N-Gain} = \frac{\textit{Postest Score} - \textit{Pretest Score}}{\textit{Maximal Score} - \textit{Pretst Score}}$$

The categories of effectiveness according to Hake (1998) based on N-gain score are presented in Table 4.

Table 4
Gain scoring category

N-Gain Score	Category
g > 0.70	High
0.30 ≤ g < 0.70	Medium
g < 0.30	Low

(Hake, 1999)

FINDINGS

The results of the normality and homogeneity of variance tests on students' conceptual and algorithmic understanding data are presented in Table 5.

Table 5
Results of normality and homogeneity of variance tests for conceptual and algorithmic understanding

Category		Normality (Kolmogorov-Smirnov[a])		Homogeneity of Variance	
		N	Sig.	Levene Statistic	Sig.
Conceptual	Pretest	64	0.000	0.615	0.436
Understanding	Posttest	64	0.001	0.816	0.370
Algorithmic	Pretest	64	0.005	0.281	0.598
Understanding	Posttest	64	0.031	0.827	0.367

Based on Table 5, the pretest and posttest data on students' conceptual and algorithmic understanding were abnormally distributed (Sig. < 0.05) and homogeneous in variance (Sig. > 0.05). Because the data gathered were not normally distributed, then a nonparametric statistical test, Mann-Whitney U, was conducted. The results of students' conceptual and algorithmic understanding pretest and posttest using Mann-Withney U test in both verification and EIGER classes are presented in Table 6.

Table 6
Pretest and posttest results for students' conceptual and algorithmic understanding in the verification and EIGER classes

Category		Mann-Whitney U	Asymp. Sig. (2-tailed)
Conceptual Understanding	Pretest	406.500	0.154
	Posttest	136.000	0.000
Algorithmic Understanding	Pretest	440.000	0.339
	Posttest	317.000	0.009

Table 6 shows that the differential test using Mann-Whitney U on students' conceptual and algorithmic understanding pretest data yielded sig. values $p = 0.154$ (sig > 0.05) for the conceptual understanding category and $p = 0.339$ (sig > 0.05) for the algorithmic understanding category. This means that there was no difference in initial abilities between the verification class and the EIGER class. The differential test with Mann-Whitney U on the posttest data yielded sig. values $p = 0.000$ (sig < 0.05) for the conceptual understanding category and $p = 0.009$ (sig < 0.05) for the algorithmic understanding category. This means that there was a difference between the verification class and the EIGER class in improving their conceptual and algorithmic understanding after learning. Therefore, this research was able to answer the two problems of this research. Firstly, there was a difference in conceptual understanding between students instructed with the EIGER learning strategy and those instructed with the verification learning strategy in topics of stoichiometry. The improvement of conceptual understanding in students instructed with the EIGER learning strategy was greater than that in students instructed with the verification learning strategy. Secondly, there was a difference in algorithmic understanding between students instructed with the EIGER learning strategy and those instructed with the verification learning strategy in topics of stoichiometry. The improvement of algorithmic understanding in students instructed with the EIGER learning strategy was greather than that in students instructed with the verification learning strategy.

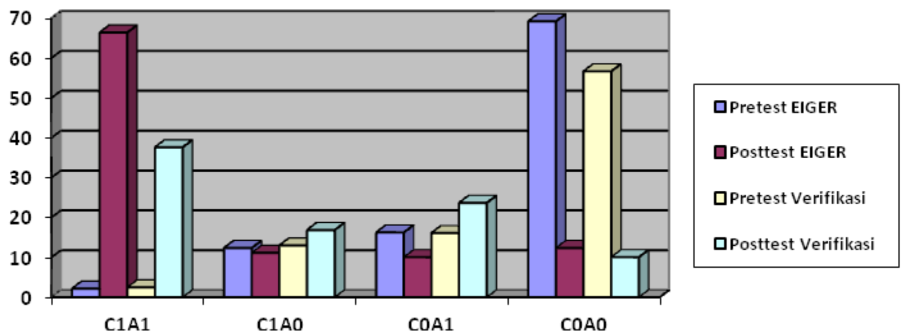

Figure 2
The results of the pretest and posttest of students' conceptual and algorithmic understanding for the verification and EIGER classes

The improvements of conceptual understanding and algorithmic understanding in the EIGER class were significantly higher than the improvements of conceptual understanding and algorithmic understanding in the verification class. Such a conclusion is supported by the percentages of improvements in conceptual understanding and algorithmic understanding from the pretest and posttest and by the average N-gain score. The percentages of improvements in conceptual understanding and algorithmic understanding based on the pretest and posttest data for the verification class and the EIGER class can be seen in Figure 2.

The data in Figure 2 show that the percentages of improvements in students' conceptual understanding and algorithmic understanding were higher in the EIGER class than in the verification class. Such results are also supported by the N-gain score data. The N-gain scores of the class taught with the EIGER learning strategy and the class taught with the verification learning strategy can be seen in Table 7.

Table 7
N-gain scores of the verification and EIGER classes

Category	Class	N-Gain Score
Conceptual Understanding	Verification	0.52
	EIGER	0.73
Algorithmic Understansding	Verification	0.60
	EIGER	0.76

Based on the criteria set by (Hake, 1999) as shown in Table 4, the conceptual understanding of the EIGER class had a high level of effectiveness, while the conceptual understanding of the verification class had a medium level of effectiveness. As for the algorithmic understanding, the EIGER class had a high level of effectiveness, while the verification class had a medium level of effectiveness. From the N-gain scores and effect sizes of students' conceptual and algorithmic understanding, it was concluded that the

EIGER learning strategy was more effective to improve conceptual and algorithmic understanding than the verification learning strategy.

DISCUSSION

The data analysis results show that the conceptual and algorithmic understanding in the EIGER class were significantly higher than those in the verification class. In other words, the implementation of the EIGER learning strategy had a positive effect on students' abilities in terms of conceptual and algorithmic understanding. In the verification class, the teacher dominated by giving information and explanations to the students, so the students were at the passively receiving end. Verification instructions are teacher-centered and make students learn by memorization. Teacher-centered instructions do not give students many opportunities to interact with each other in order to improve their skills, neither do they give students opportunities to learn independently; they are more toward waiting for information to be taught to the students (Khuvasanond, 2013). Traditional instructions like verification instructions do not give students opportunities to actively engage in learning tasks, build their knowledge, and work collaboratively; they are not enough to improve students' confidence and understanding (Tarkin et al., 2017). On the other hand, EIGER instructions are student-centered. The implementation of student-centered instructions can stimulate students' development in order for them to move around more actively, gain the ability to solve problems and understand causality concepts, have courage to express their opinions, cooperate, and help each other (Suwarjo et al., 2015). EIGER instructions are of the constructivist type. From the constructivist perspective, students actively build knowledge by continuously assimilating and accommodating novel information (Slavin, 2006). In EIGER instructions, students are taught how to find concepts and apply such concepts to solve problems, so the conceptual understanding and algorithmic understanding of the students in the EIGER class were higher than those of the students in the verification class. Learning concepts is critical as it is part of the process of gaining a correct understanding, in which case new knowledge can make better of the concepts that are already well-organized in the mind (Bilgin et al., 2009; Bybee et al., 2006). For students to understand concepts, in the implementation of EIGER instructions students must be frequently engaged in argumentation. Therefore learning with the EIGER learning strategy can improve conceptual understanding, with which students can solve algorithmic problems. Students' conceptual understanding can be developed by engaging students in argumentation as argumentation is an alternative way to find out students' thinking abilities (Venville & Dawson, 2010).

In the engagement stage of EIGER instruction implementation, students are reminded of previous learning materials that are relevant to the material to be learnt, so they can recall the materials that they have ever learnt previously, and the teacher can make corrections to misconceptions. As posited by (Hanson, 2016), preexisting knowledge can influence students' learning of new concepts. Thus, the only key factor that affects teaching and learning for concept development is finding out what is known to students before each instruction so formation of alternative concepts can be avoided (Hanson, 2016). According to Ausubel's theory of meaningful learning (Stott, 2020), instructions occur through the merging of new information into a preexisting knowledge scheme, either through simple assimilation or through a more intricate accommodation process. Accommodation is required if the existing knowledge is incompatible with the new one, making it necessary to make alterations before an instruction takes place. Then, students are guided to find new concepts in the investigation stage by engaging them directly in a practicum or by giving them concrete data so they can analyze such data and discover new concepts. According to (Stott, 2020), instructions that provide facts on the interconnection between one concept and another can promote conceptual understanding. After students' understanding is formed, the students are taken to a problem in the guided-connection stage, so it can be discovered whether the concepts formed can be applied correctly by the students in solving problems and it can be ensured that no alternative concepts are used by the students in their problem-solving activity. Misconceptions or alternative concepts can cause as many a repetition of the same mistakes as possible if students' misunderstanding is not identified and handled properly. Such mistakes are what cause it difficult for students to understand concepts (Hanson, 2016). In the evaluation and reflection stage, the instruction is ended with evaluating students' understanding in solving conceptual and algorithmic problems. Afterward, students' understanding is reflected, hence misconceptions can be avoided.

The learning outcomes of students taught with the EIGER learning strategy and those taught with the verification learning strategy increased, both in conceptual and algorithmic understanding. High conceptual understanding of the students also caused their algorithmic understanding to be high because conceptual understanding requires a higher level of cognitive abilities than algorithmic understanding does (Slesnick, 1982; Bilgin et al., 2009). Based on the conceptual and algorithmic understanding, students' understanding categories in the chemistry class are as follows. Firstly, students who were able to solve conceptual and algorithmic problems correctly (A1C1) were those who were categorized as successful. Students with higher levels of abilities both in conceptual and algorithmic understanding were able to demonstrate better abilities to collect information (Gulacar et al., 2019). Students who had better conceptual and algorithmic understanding could implement relevant chemical principles and concepts appropriately to solve problems. Additionally, they tended to understand chemical concepts not only at the macroscopic level, but also at the microscopic level (Coştu, 2007; Nakhleh & Mitchell, 1993). Secondly, students with a high level of conceptual understanding and a low level of algorithmic understanding (A0C1) were a rare case because students in this category were those who understood concepts but could not solve algorithmic problems accurately. They tended to make errors in their calculations or tended not to be able to connect conceptual understanding to algorithmic understanding in applying their knowledge (Coştu, 2007; Nakhleh & Mitchell, 1993), probably because of a lack of declarative knowledge that was well and structurally organized and they might need before a transfer to procedural knowledge. In other words, students' difficulty in applying their conceptual knowledge to solve problems was probably not caused by their lack of knowledge, but more by the structure of their preexisting knowledge that could inhibit the transfer to the problems faced (Chiu, 2001; Coştu, 2007). Thirdly, the existence of students who were at a low level of conceptual understanding and a high level of algorithmic understanding (A1C0) implies that low-performing chemistry students were unable to solve chemical problems accurately (Coştu, 2007). This category included students who only memorized and repeated rules without understanding the underlying chemical concepts. Students who had a high level of algorithmic understanding and a low level of conceptual understanding were able to execute calculations to solve algorithmic problems, but this success did not necessarily guarantee that they had mastered the concepts correctly to solve conceptual problems (Nakhleh & Mitchell, 1993). Lastly, students who were with a low level of conceptual understanding and a low level of algorithmic understanding (A0C0) belonged to the category of students who failed to understand the learning materials. These students experienced difficulties in solving problems, and in the way they tried to solve problems it was clear that they did not know of what they had to do especially in solving algorithmic problems (Bordner & Herron, 2002; Chiu, 2001; Nakhleh & Mitchell, 1993; Salta & Tzougraki, 2010). Students' ignorance of what they had to do indicated a poor conceptual understanding as a result of working memory overcapacity (Gulacar et al., 2019).

CONCLUSION

This study found that students' conceptual and algorithmic understandings after instructed using the EIGER learning strategy were outperformed compared to the students' conceptual and algoritmic understandings after instructed using verification learning strategy. The findings of this study have implications for teachers that the EIGER learning strategy can be applied to enable students not only to apply their algorithmic understanding but also their conceptual understanding because in EIGER learning students are taught how to find concepts and at the end of the investigation stage there is a concept validation stage, so that the concepts understood by students will be the correct ones.This EIGER learning strategy can be implemented particularly in chemistry topics that require both conceptual and algorithmic understandings.

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