Educación Química

The Effectiveness of the "EMBE-R" Learning Strategy in Preventing Student's Misconception in Chemical Equilibrium

La eficacia de la estrategia de aprendizaje "EMBE-R" para prevenir los conceptos erróneos de los estudiantes sobre el equilibrio químico

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Abstract

This study has been carried to compare the effectiveness of EMBE-R (Engage, Modification, Building concept, Evaluation-Reflection) and verification strategies in preventing misconceptions in Chemical Equilibrium (CE). This study involved into two groups of students majoring in Natural Sciences from senior high school one located in South Sulawesi, Indonesia. The two groups have been fulfilled the homogeneity requirements. One group consisting of thirty-five students was taught using EMBE-R strategy. Another group, also consisting of thirty-five students, was taught using verification strategy. Student's misconceptions were identified using a three-tier diagnostic instrument on CE (TT-DICE). The effectiveness of the two strategies was also examined based on student's Scientific Reasoning Ability (SRA). Student's SRA was measured using the Classroom Test of Scientific Reasoning (CTSR) developed by Lawson. The descriptive analysis used to compare the number of misconceptions held by students in both groups. The study indicated that students who were taught with the EMBE-R strategy had four misconceptions, while the verification had nine-teen misconceptions. Besides, both in the two levels of SRA, i.e., high and low level, EMBE-R strategy is more effective in preventing misunderstandings than verification strategy. Thus, the EMBE-R strategy is more effective in preventing misconceptions in CE than verification strategy.

Keywords

EMBE-R strategy, verification, misconception, chemical equilibrium

Resumen

Este estudio se ha llevado a cabo para comparar la efectividad de EMBE-R (Engage, Modification, Building concept, Evaluation-Reflection) y las estrategias de verificación para prevenir conceptos erróneos en Chemical Equilibrium (CE). Este estudio involucró a dos grupos de estudiantes con especialización en Ciencias Naturales de la escuela secundaria superior ubicada en el sur de Sulawesi, Indonesia. Los dos grupos han cumplido los requisitos de homogeneidad. A un grupo formado por treinta y cinco estudiantes se les enseñó utilizando la estrategia EMBE-R. A otro grupo, también compuesto por treinta y cinco estudiantes, se le enseñó utilizando la estrategia de verificación. Los conceptos erróneos de los estudiantes se identificaron utilizando un instrumento de diagnóstico de tres niveles en CE (TT-DICE). La eficacia de las dos estrategias también se examinó en función de la capacidad de razonamiento científico (SRA) del estudiante. El SRA del estudiante se midió utilizando la Prueba de Razonamiento Científico en el Aula (CTSR) desarrollada por Lawson. El análisis descriptivo utilizado para comparar el número de conceptos erróneos sostenidos por los estudiantes en ambos grupos. El estudio indicó que los estudiantes a los que se les enseñó con la estrategia EMBE-R tenían cuatro conceptos erróneos, mientras que la verificación tenía nueve conceptos erróneos. Además, tanto en los dos niveles de SRA, es decir, nivel alto como bajo, la estrategia EMBE-R es más eficaz para prevenir malentendidos que la estrategia de verificación. Por lo tanto, la estrategia EMBE-R es más eficaz para prevenir conceptos erróneos en CE que la estrategia de verificación.

Palabras clave

Estrategia EMBE-R, verificación, concepción errónea, equilibrio químico

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Introduction

Chemical Equilibrium (CE) topic consists of many concepts that are closely related to concepts on the next topics such as acid-base equilibrium, solubility, and hydrolysis (Voska & Heikkinen, 2000; Berquist & Heikkinen, 1990). Most concepts in CE have been defined concepts derived from objects or events abstract (Ertmer *et al.*, 2003; Effendy, 2002). These concepts tend to be appropriately understood by students who have been developed Scientific Reasoning Ability (SRA). According to Lawson *et al.* (2000), SRA is the ability of students to think about conservation, proportion, identification, control of variables, probabilities, correlations, and deductive hypothesis. The SRA is developed from Formal Reasoning Capability (FRC) by Lawson (1978) and Lewis & Lewis (2007), which includes the ability of students to think about proportion, probability, correlation, and combination. Thus, the FRC is same thing with the SRA, with the addition of the ability to think deductive-hypothetic.

FRC or SRA is owned by students who have been reached the level of formal thinking based on Piaget's theory of intellectual development (Baldwin, 1967). Based on the age norm set by Piaget, FRC, or SRC should have been developed by children with the age of 12 years. However, previous research results reported that many students aged 12 years or older have not been developed SRC yet. Abraham *et al.* (1994) reported that only 61.0% of high school students in the United States reached the SRA. Only 57.4% of high school students in Cyprus achieved an SRA (Valanides (1999). Budiasih (2011) stated that only 50.9% of high school students in Malang had reached the SRA. There is only 41.0% of Puerto Rico University students who take the Basic Chemistry course at Rio Piedras have been reached the level of formal thinking (Bird, 2010). Mary & Gumel (2015) reported that only 70.0% of Chemistry students in Nigeria developed SRA. A possible effect of these facts is that concepts in CE have potential to be difficult for most students to understand. This difficulty can lead to misunderstandings which if occur consistently can result in misconception. A misconception is the understanding of concepts not following the knowledge of the scientific community (Barke *et al.*, 2009; Herron, 1996; Nakhleh, 1992). Misconceptions are also called as alternative concepts (Horton, 2007).

Efforts to overcome the misconceptions that have been carried out so far tend to be remediation. Remediation with conceptual change strategy has been done by Pabuccu & Geban (2006) on Chemical Bonding topic, Atasoy *et al.* (2009) and Canpolat *et al.* (2006) on Chemical Equilibrium topic. Remediation using mental model has been done by Chiu *et al.* (2002) on CE topic. Niaz (2001) has done remediation using cognitive conflict strategy on CE topic. However, remediation tends to be less efficient because it requires relatively long time. Another possibility is the persistence of student misconceptions. Thus, prevention will be better than remediation (Taber, 2002).

Review of Literature

Student's Misconceptions About Chemical Equilibrium,

Several researchers have been reported misconceptions concepts in CE topic. Some of them are as follows. The forward reaction rate will increase when the reaction approaches equilibrium (Hackling & Garnett, 1985; Niaz, 1998a). The state of equilibrium occurs when the concentration of reactants and products are the same (Yakmaci-Guzel, 2013; Barke *et al.*, 2009; Ozmen, 2008; Hackling & Garnett, 1985). The rise in temperature implies that the forward reaction rate decreases, and conversely, the rate of reverse reaction increases (Barke *et al.*, 2009; Bilgin & Uzuntiryaki, 2003; Hackling & Garnett, 1985). Catalysts increase yields (Barke *et al.*, 2009; Bilgin & Uzuntiryaki, 2003; Gorodetsky & Gussrasky, 1986). In an equilibrium state, the reaction does not occur (Ozmen, 2008). Equilibrium is a static process (Yakmaci-Guzel, 2013; Barke *et al.*, 2009). In exothermic reactions, increasing temperature will reduce the rate of the forward reaction (Sozbilir *et al.*, 2010; Banerjee, 1991). The significant value of K causes a fast reaction (Banerjee, 1991; Gorodetsky & Gussrasky, 1986; Hackling & Garnett, 1985). The addition of reactant's solid phase at heterogeneous equilibrium systems causes the reaction shift towards the product (Sendur *et al.*, 2011; Piquitte & Heikkinen, 2005). The addition of reactants to the gas equilibrium system will shift the equilibrium towards the product (Karpudewan *et al.*, 2015). Based on the results above, it shows that misconceptions occur in almost all concepts of CE.

There are many conclusions put forward by experts relating to the source of misconceptions. Misconceptions of chemical concepts, including CE, are due to insufficient understandings of prior knowledge (Garnett *et al.*, 1995) as conjectured by Garnett *et al.* (1995). The sources of misconceptions in CE may stem from student's preconceptions (Barke *et al.*, 2009). Insufficient initial knowledge is related to the teacher (Devetak *et al.*, 2010; Bilgin & Uzuntiryaki, 2003).

Aside from initial knowledge, misconceptions are also caused by daily experiences. Some reports are as follows. Chemical equilibrium is a static one (Bilgin & Uzuntiryaki, 2003). This misunderstanding arises because students see objects like a balanced glass on the table because the glass does not move. Dissolving sugar in water requires heat and stirring (Blanco and Prieto, 1997). This misconception arises because before entering school, students often see that to make sweet tea sugar is dissolved in hot water then stirred. Low student's attention and inaccurate understanding of textbooks (Erman, 2017; Devetak *et al.*, 2010), abstract, symbolic, language usage, and incorrect terms (Yakmaci-Guzel, 2013) can also be a cause of misconception. A misconception is a serious problem that may impact and hurdle the learning of subsequent concepts (Durmaz, 2018; Ilyas & Saeed, 2018; Papaphotis & Tsaparlis, 2008). Therefore misconception must be prevented.

As described above, a reason of misconception is due to insufficient understanding of prior knowledge or prior related concept. Taber (2009) & Taber (2015) argue that student's difficulty in understanding chemical topics is due to their inabilities in connecting the basic concepts with the one. Arends (2012) stated that student's understandings could be built when teachers select and identify student's experience and prior knowledge. Arends & Kilcher (2010) suggested that it is essential to set learning strategies that can connect student's knowledge and the concepts of topics. The students need to have prior knowledge about the rate of reactions (RR) before learning CE (Effendy, 2002; Ganesen & Shamuganathan, 2017). Thus, it is necessary to provide a proper understanding of the prerequisite concepts in RR before studying chemical equilibrium topic.

Several factors that cause concepts in CE tend to be difficult to understand and can even lead to a misconception, namely: (1) The nature of concepts in CE, which is generally well-defined concepts. (2) Learning that, does not stimulate student's intellectual development. (3) Lack of student's ability in terms of understanding is the triple representation interrelations. (4) Prerequisites concepts have not been appropriately understood, even misconceptions occur. Therefore it is necessary to design a learning strategy that can prevent misconceptions in CE.

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Characteristics of Learning Strategy Considered to be Able to Prevent Misconceptions in Chemical Equilibrium

The strategy chosen is based on inquiry-based learning was firstly developed by John Dewey (Bybee & Taylor, 2006). This strategy is based on the "mental functioning model" of Piaget, which emphasizes assimilation and accommodation. The selected strategy adapts the 5E learning cycle developed by Abraham & Renner (1986). Learning cycle includes five stages: engagement, exploration, explanation, elaborate, and evaluation, namely LC5E. LC5E is the development of LC "verify-inform-practice" by Atkins & Karplus (Cracolice, 2009). The strategy developed is like to be effective in preventing student's misconceptions in CE because it has the following characteristics.

First, learning begins by exploring and strengthening the prerequisite concepts is necessary to build a proper understanding of concepts in CE. These aims used to produce an appropriate understanding of the prerequisite concept. The prerequisite concepts are the rate of reaction, exothermic and endothermic, and mol concept. The learning should emphasize building a proper conceptual understanding based on prerequisite concepts (Han, 2013).

Second, learning must optimally stimulate student's thinking abilities. Students who have developed their thinking skills can potentially understand concepts more easily and precisely. Dewey argues that learning strategies that can stimulate student's intellectuals are inquiry-based learning (Bybee & Taylor, 2006).

Third, learning that, involves macroscopic, submicroscopic, and symbolic representations. Russel *et al.* (1997) suggested that learning by involving the three representations can reduce student misconceptions.

Fourth, learning emphasizes the process of building conceptual understanding based on its prerequisite concepts (Han, 2013). The process is accompanied by questions of stimulation, guidance, strengthening concept, and validation concept. In this learning, understanding concept is more emphasized than algorithmic. Gultepe *et al.* (2013) suggested that learning by emphasizing understanding concepts can be more effective in solving algorithmic problems.

Fifth, learning that, emphasizes evaluation and reflection. This reflection is important as one of the characteristics of a kind learning strategy and follow-up evaluation conducted (Arends & Kilcher, 2010: 370).

Based on these five characteristics, a new learning strategy called EMBE-R learning strategy is developed. This strategy involves four stages, starting from the engagement stage, intended to engage students physically and mentally in the learning process by exploring their understanding of prerequisite concepts. This stage is based on information processing theory that importance of motivation at the beginning of learning (Gagne *et al.*, 2005). The next is a modification stage intended to fix student's understanding of the prerequisite concept based on conceptual change theory (Carey, 2000; Bodner, 1986; Posner *et al.*, 1982), scheme theory (Piaget, 1977), and the modified theory of Toulmin (Duit & Treagust, 2003). The modifications occur if student's understanding of prerequisite concepts is not sufficient to reach the new one. So, students need to rearrange or modify their conceptions.

The third is a building concept that intends to build a complete conceptual understanding of students with a proper understanding of prerequisite concepts. Activities at this stage are exploring, analyzing, explaining, communicating, reinforcing, and validating concepts. Based on Piaget & Vigotsky's ideas (Bodner, 1986), this stage tries to involve students in activating

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cooperative learning, so that learning becomes meaningful (Novak, 2002). Thus, the information received can be stored in student's long-term memory (Gagne *et al.*, 2005). Besides, learning based on inquiry with an emphasis is actively involved in the process of building new concepts and facts, not only on exploring existing facts (Dostal, 2015). Inquiry questions are maximized to stimulate the development of student's scientific reasoning abilities (Zimmerman, 2007). This is due to intellectual stimulation that will make students experience conflict in cognitive and then balance it with the process of self-regulation. Lawson *et al.* (1975) argue that self-regulation can develop student's reasoning abilities. Students with high SRA will be more easily to build conceptual understanding. Thus, students can analyze and choose concepts that are more reasonable and appropriate for themselves. Finally, the evaluation-reflection stage is intended to measure individual student achievement and for teachers, is used to reflect and evaluate the learning process (Arends & Kilcher, 2010; Fry *et al.*, 2009). Four phases of the learning strategy are formulated, namely engagement (E), modification (M), building concepts (B), evaluation-reflection (E-R). This is called the EMBE-R strategy, which is expected to prevent misconceptions about the concept of CE.

The strengths of the EMBE-R strategy are: (1) Making students' understanding of CE prerequisite concepts appropriate. This stage carried out by eliminating misconceptions if any. (2) Improving student SRA is facilitated by providing inquiry questions for quality intellectual stimulation. This activity is assisted by student worksheets. (3) Learning involves three representations always used in discussing chemical phenomena. In this section the teacher uses Power point, animation, and video as learning aids. (4) Providing a solid foundation in understanding new related concepts. The cultivation of appropriate prerequisite concepts creates a strong foundation in building new concepts that are related. Complete understanding of the concept can prevent misconceptions.

CE teaching in senior high schools in Indonesia mostly uses verification strategy. This strategy consists of four main steps: (1) teacher's explanation of concepts to students, (2) exercise and class discussion, (3) laboratory activity to verify the concepts explained, and (4) assessment. This strategy is implemented in senior high schools three in Gowa Regency. This strategy gives low achievement of specified competencies, namely the minimum completeness criteria (MCC). An interview with one of the chemistry teachers in those school indicates that the average MCC for chemical equilibrium is less than 50%. Blanchard *et al.* (2010) reported that the verification approach gave lower learning outcome than an inquiry approach. Since EMBE-R strategy is based on inquiry, teaching CE using EMBE-R strategy gives higher learning outcome than verification strategy.

Research Problems

The problems of this research are: (1) Is the EMBER strategy more effective than a verification strategy in preventing student misconceptions in the CE topic? (2) Is the EMBE-R strategy more effective than a verification strategy to prevent misconceptions in CE at different SRA levels?

Methodology of research

Research participants were two groups of eleventh-grade students of senior high school in Gowa, South Sulawesi, Indonesia. The participant was randomly taken from eight homogenous classes in the school. One group (experimental group, EG) consists 35 students

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was taught using EMBE-R strategy. Another group (control group, CG) also consists 35 students, was taught using verification energy. These two groups may be regarded to be homogenous based on their ability in mastering prerequisites concepts. The teaching of CE using EMBE-R and verification strategies conducted in 8 class meetings, with a duration of 90 minutes for each session. Both classes are taught with the same duration of learning, teacher, media, and type of test. The difference is only in the treatment of learning.

EMBE-R strategy consists of four stages. The first stage is the engagement. This stage is used to prepare students physically and mentally to learn, to review and identify possible misconception related to prerequisites concepts. The second stage is a modification. This stage is used to eliminate misconception of prerequisites concepts using cognitive conflict strategy. The third stage is building a new concept. Student activities in this stage are observing data or animated videos, analyzing and discussing the data with group members. Build concepts have done by optimizing stimulus questions, class discussions, and concluding findings. Strengthen concepts with practice have been accompanied by communicating them in class, and validating processes from other groups and teachers. The fourth stage is evaluation and reflection. In this stage, an individual test is given at the end of each meeting. Verification strategy is a learning that often applied by the teachers with the steps outlined earlier.

Instrument

Initial Ability Test

The initial ability test (IAT) is twenty-five items multiple-choice developed by (Sozbilir *et al.*, 2010; Nakhleh, 1992). The test comprehends six items about moles and reaction equations concept, two items of the ideal gas equations concept, two items of exothermic and endothermic reactions concept, and fifteen items in the concept of reaction rates. The content validity from three experts and three practitioners towards IAT suggested that the validity value is 90.7%, which is very high category. The coefficient of reliability test involving thirty-six students tested using Cronbach's alpha. The reliability test showed that the score was 0.81 (high). This instrument was used to test the similarity of the initial abilities of the two groups.

Three-tier Chemical Equilibrium Diagnostic Test

The three-tier diagnostic instrument on chemical equilibrium (TT-DICE) consists of thirty items was developed by (Jusniar *et al.*, 2020). The TT-DICE consists of six items in the concept of equilibrium conditions and dynamic equilibrium, and four items in the concept of equilibrium reaction types. Besides, it consists five items in the concepts of Kc and Kp, the factors that influence it, and the determination of the concentration of substances in equilibrium conditions. Two items in the concept of constant K on heterogeneous equilibrium. Eleven items of concept which is factors that affect the shift in equilibrium, and two items of the concept of chemical equilibrium applications in the industry.

The first tier in the form of questions consisting of four answer choices, the second tier is a reason consisting of four choices of reasons, and the third tier contains the level of confidence from answers and reasons with three choices namely 1) guess, 2) not sure, and 3) sure. TT-DICE has very high validity, i.e., 96.1%. The reliability test involved 35 students who were tested using Cronbach's alpha. The reliability test showed that the score was

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0.95 (very high reliability). The empirical validity test results suggested that 28 items were valid, ranging from 0.360 to 0.922, and the other two items were quite valid (items 9 & 10) with r 0.324 & 0.215. The writer was determining the students who have misconceptions on TT-DICE, adapting the criteria set by Arslan *et al.* (2012) as in Table 1.

Table 1. Criteria of Grouping Conception Students Based on Three-tier Test

First-tier	Second-tier	Third-tier	Category
True	True	Sure	Scientific Comprehension
True	True	not sure / guess	Scientific Comprehension
True	False	not sure / guess	Less Comprehension
False	True	not sure / guess	Less Comprehension
False	False	not sure / guess	Less Comprehension
True	False	Sure	Misconception
False	True	Sure	Misconception
False	false	Sure	Misconception

Data on the number of misconceptions TT-DICE used to determine the effectiveness of the EMBE-R strategy to prevent student misconceptions in CE material.

The Classroom Test of Scientific Reasoning

The classroom tests scientific reasoning (CTSR) by Lawson *et al.* (2000) has been translated and validated. CTSR consists of twenty-four items with the distribution, i.e., four items of conservation thinking, four items of proportional reasoning, two items of variable control, four items of probability reasoning, two items of correlation reasoning, and four items of hypothetic-deductive reasoning (Han, 2013). The empirical validity test results showed the range of r from 0.187 to 0.665, consisting of 18 valid items, and six questions were entirely valid. The reliability test involved 35 students was calculated using Cronbach's alpha with Statistical Package for the Social Sciences (SPSS) showed was 0.75 (high reliability).

Data Analysis

a. The analysis of the Initial Ability of the Two Groups

b. The analysis technique used to identify student's initial abilities as the basic of CE learning is a *t-test*. Analysis of the *t-test* was carried out with the SPSS program after the prerequisite test (normality and homogeneity) had been fulfilled.

c. The effectiveness of the EMBE-R strategy in preventing the misconception of CE is determined by a comparison of the number of misconceptions held by students in the control and experiment groups based on the categories by Dhindsa & Treagust (2014), Al-Balushi *et al.* (2012), and Peterson *et al.* (1986). A misconception was considered a common misconception if 20.0% or more of the sample believed in it.

d. The effectiveness of the EMBE-R strategy in preventing misconceptions was determined by comparing the number of misconceptions with high and low SRA levels, both in control and experiment groups. The determination of high and low SRA was based on the categories stated by Bridges & Harnish (2015).

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Results and discussions

1. The Results of the Initial Ability Test

The results of the student's initial ability scores both in the control and the experiment group are presented in Table 2c. The results of the t-test were carried out after the prerequisite test (normality and homogeneity) was satisfied, as presented in Tables 2a and 2b.

Table 2a. The Results of Normality Test of Student's Initial Ability Scores

The value of KS calculates from output SPSS is the value of most extreme differences absolute.

Variables tested	Test used	Criteria	*KS* count	*KS* table	Conclusion
IAT Score Control Group (CG)	Kolmogorov-Smirnov Test (*KS*)	IAT Score Normal Distribution If $KS_{count} < KS_{table}$	0.115	0.224	IAT Score CG Normally Distributed
IAT Score Experiment Group (EG)			0.110	0.224	IAT Score EG Normally Distributed

Table 2b. The Result of Homogeneity Test of Student's Initial Ability Scores

Variables tested	Test used	Criteria	F_{Count}	F_{Table}	Conclusion
Score IAT CG - EG	Levene's test Statistic	Variance homogeneous if $F_{Count} < F_{Table}$	3.49	3.98	CG-EG homogeneous of Variance

Table 2c. The Summary of t-test of Student's Initial Ability Score

Variables tested	Test used	Test criteria	t_{count}	t_{table}	Conclusion
IAT Score CG – EG	*t*-test two tails	Reject H_0, if the value of $t_{count} > t_{table}$	0.26	1.99	Accept H_0, meaning both groups are the same.

Based on Table 2c, it is known that $t_{count} < t_{table}$, which means that the control and experiment groups are the same. Thus, the students have homogeneous initial abilities. The results of the effectiveness of the EMBE-R strategy in preventing CE misconceptions are presented in Table 2c. The description of the number of misconceptions of CE experienced by the students both in the control and experiment groups with different SRA levels is given in Table 4a.

2. The Effectiveness EMBE-R Strategy to Preventing CE Misconceptions in the Different SRA

The data in Table 4a-d shows the average percentage of misconceptions experienced by students in the EG is smaller than in the CG. Based on Al-Balushi *et al.* (2012) criteria, it can be assumed that students in the experimental group did not experience misconceptions, while the control class still had misconceptions. It implies that the experiment group successfully prevents misconceptions. Thus, the learning with the EMBE-R strategy in the experiment group can be said more effective in preventing misconceptions than verification strategy. The effectiveness EMBE-R strategy in preventing misconceptions was indicated by comparing the number of misconceptions students experience in the control and experiment groups. In the experiment group, there are four students who have misconceptions, while in the control group, there are nineteen students who have misconceptions.

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Pekmez (2010) suggests that a learning has been said able to prevent misconception if it produces a smaller number of misconceptions. The same argues stated by Sesen & Tarhan (2010) that the small number of misconceptions experienced by students shows the effectiveness of a learning strategy.

The data in Table 3 shows that students with high and low SRA have the same average number of misconceptions in the control group. Meanwhile, in the experimental group, the number of misconceptions were experienced by students with high SRA levels, was smaller than the low SRA levels. Students with high SRA levels understand the concepts more easily than students with low SRA levels. Students with high SRA can do the process of thinking correlation, combination, proportion, and hypothetical deductive. The ability is needed to understand CE concepts, which are loaded with conceptual and algorithmic understanding. The fact is consistent with Lawson’s (2004) opinion that students with high-level SRA already can think correlation, combination, probability, and hypothetical deductive. Thus, these students have been able to analyze and choose concepts that make sense and appropriate.

The contribution of understanding is the appropriate prerequisites concept at the modification stage that makes students easier to develop the concepts of CE in the building concept stage. The activities at this stage optimize student involvement both physically and mentally. Students physically work together in small groups in doing a worksheet, answer questions to build an understanding of concepts, discuss within groups, and with the other groups in communication activities, and solve problem exercises in student worksheets in strengthening understanding concept. Relevant research by Eymur & Geban (2017) that Cooperative learning was accompanied by conceptual changes to the prevalence of chemical misconceptions and can improve student’s conceptual understanding. Mental activities that accompany student’s physical activities include observing the presentation media or video, analyzing data, presenting media, and doing discussion. This process, based on inquiry learning, can make students active in the classroom, help them learn in a fun way, and help them gain depth about concepts (Zubaidah *et al.*, 2017).

Table 3. Number of Misconceptions of CE at Different SRA.

Levels of SRA	Control class			Average NM	Experiment class			Average NM
	N	NM	%		N	NM	%	
High	16	123	7.9	8	18	47	2.6	3
Low	19	148	7.8	8	17	73	4.3	4

Description: N = The number of students’; NM = The number of students’ misconceptions

The activity is supported by the concept validation process and self-reflection of students with monitored by the teacher at each stage in the EMBE-R strategy. The first validation was carried out at the end of the modification stage with oral questions regarding the reconstruction of misconceptions experienced by students in the prerequisite concepts. The second validation has been done verbally after the activity of communicating (discussing) to build the right understanding of the CE concept. The third validation and reflection are in the form of a written test at the end of each meeting. The validation and reflection are carried out simultaneously to produce a prover understanding of the CE concepts. As Osborne & Wittrock (1983) suggested that learning which attempts to associate several concepts can make students validate the concepts they build.

The data in Table 4a-4d showed that, in general, the average percentage of misconceptions in the control group is greater than the experiment group. Based on the

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categories by Al-Balushi *et al.* (2012), Dhindsa & Treagust (2014), and Peterson *et al.* (1986) that misconception is considered to occur if 20.0% or more of the sample believed in it. In other words, misconceptions are experienced by students who were taught with verification learning. However, it was not considerably occurred in students who were taught with the EMBER strategy.

3. Study of the Comparison the Effectiveness of EMBE-R and Verification Strategies Student's ideas of when equilibrium is achieved

Table 4a shows eight student's ideas classified as misconceptions about when the equilibrium situation is reached. In CG, there are six misconceptions that students believe, whereas, in EG, only one misconception. This shows that student's understanding of the concept of equilibrium in the EG is better than the CG. The proper understanding indicates that misunderstandings about the equilibrium state at EG can be prevented compared to the CG. Making proper initial conceptual understanding of the concept of reaction rate at the modification stage makes it easy for students to build a correct understanding of the concept of achieving equilibrium.

Misconceptions (1) and (3) are experienced by students in CG about at equilibrium state, the concentration of reactants and products are the same. Students whose misconceptions identify that in $Fe^{3+}(aq) + SCN^{-}(aq) \leftrightharpoons FeSCN^{2+}(aq)$, equilibrium occurs when $[Fe^{3+}]$, $[SCN^{-}]$, and $[FeSCN^{2+}]$ are equal. This understanding is classified as a misconception because it does not follow the understanding concept of experts. It is understood that the equilibrium state of the forward reaction rate is equal to the rate of the reverse reaction. In this situation, the concentration of reactants and products is constant (no longer changing with increasing time). Meanwhile, according to Effendy (2007), the quantity of substances existing in the equilibrium system is constant in this situation. Therefore, the macroscopic symptoms or macroscopic representation of the reaction in equilibrium is constant. These symptoms can include colour, gas pressure or volume, and other symptoms. The same misconceptions have been reported by Barke *et al.* (2009) and Hackling & Garnett (1985).

Misconceptions (2) and (5) about equilibrium state and dynamic equilibrium. Students who experience misconceptions think that the forward reaction rate is higher than the reverse reaction. Misconception (4) is experienced by students in a control group This misconception is almost same like the misconceptions (2) and (5). The same misconception has also been reported by Hackling & Garnett (1985). The correct concept is that, at equilibrium, the forward reaction rate is same with the reverse reaction rate.

Tabel 4a. State of Equilibrium Misconception After Learning in the Experiment and Control Groups (N = 35).

No	Misconceptions	Misconception of EG		F_i x %	Misconception of CG		F_i x %
		F_i	%		F_i	%	
I	The state of equilibrium occurs when the concentration of reactants and products is equal	2	5.7	11.4	10	28.6*	285.7
2	At the dynamic equilibrium, the reaction rate progresses is faster than the reverse reaction.	1	2.9	2.9	11	31.4*	345.7

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3	In the same state, the reaction rate is constant, and the concentration of reactants and products is the same.	4	11.4	45.7	11	31.4*	345.7
4	In equilibrium conditions, the reaction continues with the speed of formation of reactants greater than the product.	2	5.7	11, 4	10	28.6*	285.7
5	In the equilibrium state, the rate of forwarding reaction is faster than the reverse reaction.	3	8.6	25.7	13	37.1*	482.9
6	In the equilibrium reaction, the reactants will increase, and the product will decrease then become equal	2	5.7	11.4	3	8.57	25.7
7	The state of equilibrium in the graph of the relationship of concentration to time; a straight line indicates the concentration of reactants and products is the same.	7	20*	140.0	9	25.7*	231.4
8	In an equilibrium state, the number of moles of reactants is equal to the products	3	8.6	25.7	5	14.3	71.4

Description Fi: The number of students' misconceptions.

*Misconceptions deemed to occur if experienced ≥ 20% of students by the category (Dhindsa & Treagust, 2014; Al-Balushi *et al.*, 2012; Peterson *et al.*, 1986).

Misconceptions (7) were experienced by both groups. Students identify that in the graph describing the relationship of the concentration (M) to time (s) in the reaction of $Fe^{3+}(aq) + SCN^{-}(aq) \leftrightharpoons FeSCN^{2+}(aq)$, the equilibrium condition is indicated by the formation of a straight line which indicates that the concentration of reactants and products is equal. This misconception is same with misconceptions (1) and (3). It seems that student's understanding of CG and EG in reading and analyzing graphs is still low, so it is necessary to practice them frequently.

Student's Ideas about Homogen, Heterogen, and Dissociation Equilibrium

In Table 4b, it can be seen that four misconceptions about homogeneous, heterogeneous, and dissociation equilibrium are identified. In the control group, one misconception was identified that the students believed, while in the experimental group, no misconception was assumed. A comparison of the number of misconceptions between control and experiment groups shows that students on EG have fewer misunderstandings than CG. It shows that misconceptions about homogeneous, heterogenous, and dissociation equilibrium in EG can be prevented compared to CG. The prover understanding concepts about the phases of substances and chemical bonds make it easy for students to build a correct understanding of concepts about heterogeneous and dissociation equilibrium.

"The Effectiveness of the "EMBE-R" Learning Strategy in Preventing Student's Misconceptionin Chemical Equilibrium",
Jusniar Jusnar, Effendy Effendy, Endang Budiasih y Sutrisno Sutrisno
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Misconception (12) about concept of heterogeneous equilibrium constants (K) experienced by students in the CG. Students who have misconceptions, identify the value of K_p for the reaction C(s) + CO_2(g) ⇌ 2CO (g), is $K_p = \frac{[PCO]^2}{[PC][PCO_2]}$. The student reasons that the equilibrium constant is heterogeneous is the product of the concentration with the reactant exponent to its coefficient for all phases of the substance. They understand that in heterogeneous equilibrium, the amount of solid material affects the pressure System and the K Value . Concentration of solid carbon is constant, it is incorporated into the value of the equilibrium constant and does not appear explicitly in the equilibrium expression (Burdge & Overby, 2017).

Tabel 4b. Student's Ideas about Homogen, Heterogen, and Dissociation Equilbrium.

No	Misconceptions	Misconception of EG		F_i x %	Misconception of CG		F_i x %
		F_i	%		F_i	%	
9	At homogeneous equilibrium, the concentration of reactants and products is the same	2	5.7	11.4	6	17.1	102.9
10	In heterogeneous equilibrium, the number of moles of reactants is different from the product at heterogeneous equilibrium the concentration of substances in the system is different	0	0	0	5	14.3	71.4
11	Dissociation equilibrium occurs because the number of moles of reactants and products is the same	4	11.4	45.7	4	11.4	45.7
12	Heterogeneous equilibrium constants are the quotient of the product's concentration with the reactant raised with the reaction coefficient.	6	17.1	102.9	14	40*	560.0

Student's Ideas about Equilibrium Constant

In Table 4c, it appears that there are three misconceptions about equilibrium constants identified. In the CG, there are three misconceptions that students believe, while in the EG, no misconception occurs. A Comparison of the number of misconceptions between control classes and experiments shows that students on EG have fewer misunderstandings than CG. This shows that misconceptions about equilibrium constants in EG can be prevented compared to CG.

Tabel 4c. Student' Ideas about Equilibrium Constant .

No	Misconceptions	Misconception of EG		F_i x %	Misconception of CG		F_i x %
		F_i	%		F_i	%	
13	At fixed temperatures, changes in the initial concentration of reactants caused increased the value of K_c	3	8.6	25.7	17	48.6*	825.7
14	At a fixed temperature, Kp value twice the value of Kc at equilibrium $I_2(g) \leftrightharpoons 2I^-(g)$	5	14.3	71.4	14	40*	560.0
15	In the gas equilibrium, the gas pressure is proportional to the reaction coefficient	3	8.6	25.7	7	20*	140.0

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Understanding the right concept of the reaction rate makes it easy for students to build a correct understanding of the concept of chemical equilibrium constants. The misconceptions that students believe in the control class are at a fixed temperature, changes in the initial concentration of reactants will increase K_c value (misconception 13). Students with misconceptions said that with the change in initial concentration, caused the number of reactants and products existing in the equilibrium system will change. Misconceptions (14) and (15) have the same characteristics that students understand that there is a mathematical relationship between the reaction coefficient with the K value and pressure. The true concept is chemical equilibrium constant value only affected by temperature changes.

Student's Ideas about Factors that Affect the Shift of Equilibrium

In Table 4d, it could be seen that in the control group, there are ten misconceptions out of 12 misconceptions about the factors that influence the shift in equilibrium. In contrast, in the experimental group, there are three misconceptions that students believe. Based on the comparison of the number of misconceptions, it can be seen that the number of student's misconceptions in EG is smaller than CG. It shows that misconceptions about the factors that influence the shift in equilibrium can be prevented in EG compared to the CG. The avoidance of potential misunderstandings in the EG is the success of the EMBE-R strategy. It emphasizes the cultivation of a proper understanding of the prerequisite concepts relating to the factors that influence chemical equilibrium shifts. The basic idea is the mole concept related to the change in chemical equilibrium due to changes in pressure in the gas equilibrium system. The idea of exothermic and endothermic reactions is related to shifts in chemical equilibrium due to changes in temperature. The concept of activation energy is associated with the addition of catalysts to an equilibrium system.

Tabel 4d. Misconception about Factors that Affect the Shift of Equilibrium.

No	Misconceptions	Misconception of EG		F_i x %	Misconception of CG		F_i x %
		F_i	%		F_i	%	
16	In addition to reactants in the solution equilibrium system, it does not shift the equilibrium position.	5	14.3	71.4	13	37.1*	482.9
17	Addition of volume to the solution equilibrium system will shift the equilibrium to a larger number of moles	6	17,1	102.9	4	11,4	45.7
18	Dilution in the equilibrium system will shift the equilibrium position to a smaller number of moles	7	20,0*	140	10	28,6*	285.7
19	At heterogeneous equilibrium, the change in the number of solid reactants will shift the equilibrium towards the product.	5	14,3	71.4	14	40*	560.0
20	In exothermic gas equilibrium, an increase in temperature can increase the value of K_p	6	17,1	102.9	9	25,7*	231.4
		4	11,4	45.7	6	17,1	102.9
		5	14,3	71.4	12	34,3*	411.3
21	At equilibrium, exothermic gas temperature reduction will shift the equilibrium towards formation reactants	5	14.3	71.4	7	20*	140.0

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22	In equilibrium with the number of moles of reactant gas is equal to the product, decreasing volume shifts the equilibrium towards the product.	8	22.9*	18..9	9	25.7*	231.4
23	At the equilibrium of gas with the number of moles of reactants is equal to the product, a change in pressure can shift the equilibrium position.	2	5.7	11.4	9	25.7*	231.4
24	Catalysts increase activation energy, so the reaction progresses faster than the reverse reaction.	5	14.3	71.4	11	31.4*	345.7
25	Catalysts cause the forward reaction rate to be greater than the reverse reaction.	3	8.57	25.7	5	14.3	71.4
26	An increase in gas pressure will shift the equilibrium to a larger number of moles.	7	20.0*	140	9	25.7*	231.4
27	Addition of inert gas to the system $N_2(g) + 3H_2(g) \leftrightharpoons 2NH_3(g)$ does not affect the value of K_p	3	8.6	25.7	6	17.1	102.9

Misconception (16) on the concept of solution equilibrium was experienced by students in the CG. They understand that the addition of reactants in the solution equilibrium system does not shift the equilibrium position. The addition of reactants to the solution equilibrium system will change the equilibrium towards the product's formation. Misconception (18) was experienced by students in the CG and EG. The students understand that misconceptions in the equilibrium system will shift the position of equilibrium to a smaller number of moles. It is known that adding water to the solution equilibrium system may increase the solution volume. In this condition, each species's concentration becomes small, and then the equilibrium will shift to a more significant number of molecules. Misconception (19) is same with misconception (12) discussed earlier. This misconception was only experienced by the control class. They understood that the heterogeneous equilibrium solid phase changes in the number of substances do not affect the value of *K*. This is due to the equilibrium system; the number of solid materials is fixed (Burdge & Overby, 2017). Similar misconceptions have been reported by Piquitte & Heikkinen (2005) and Sendur *et al.* (2011).

Misconceptions (20) and (21) experienced by students in the control group. They understand that in exothermic gas equilibrium, the increasing of temperature can increase the value of $K_{p.}$ The students identified that in the reaction $4NH_3(g) + 5O_2(g) \leftrightharpoons 4NO(g) + 6H_2O(g)$, ΔH = -905.6 kJ/mol, if there is an increasing in temperature, the equilibrium will shift to the right. According to them, the increasing of temperature always increases the value of K. The same finding has been reported by Voska & Heikkinen (2000) that the increasing of temperature always raises the value of K. It is understood that the increasing of temperature will shift the equilibrium towards an endothermic reaction. The latest reaction will shift to the left. The equilibrium constant for an exothermic reaction decreases as the temperature increases. The equilibrium was constant for endothermic reactions to increase as the temperature rises (McMurry & Fay, 2014).

Misconception is related to the concept of changes in pressure and volume of gas equilibrium namely misconceptions (22) is experienced by EG and CG. They understand that there is a gas equilibrium where the number of moles of reactants is equal to the

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product. Misconception (26) was experienced by EG and CG. The students understand that the increasing of gas pressure would shift the equilibrium toward a larger number of moles.

The decreasing of volume in the gas equilibrium system will shift towards product in reaction $H_2(g) + Br_2(g) \leftrightharpoons 2HBr(g)$. They assume that the number of reactants were four moles and the number of products were two moles. This misconception is caused by student's understanding in which they consider the H and Br subscript as the number of moles. The true concept is that the number of moles on both sides is equal, so the change in gas pressure/ volume will not shift the equilibrium position. The decreasing of gas volume causes a shift in equilibrium position to the small number of moles. Conversely, the increasing of volume will cause a shift towards a large number of moles (Burdge & Overby, 2017).

Misconception (24) was experienced by CG that catalysts increase activation energy implies that the forward reaction is faster than the reverse reaction. The student's realized that the catalyst is a substance that can increase reaction rate without reacting. In many cases, the catalyst increases the rate of the reaction by lowering the activation energy. Catalysts reduce energy barriers but do not affect the potential energy of reactants and products (Burdge & Overby, 2017). The comparison of the number of misconceptions in EG smaller than CG that means the EMBE-R strategy can be said effective in preventing misconceptions.

In general, from 27 misconceptions in CE, there were 19 types of misconceptions (70.4%) that were considered to occur in the CG, and only four types of misconceptions (14.8%) were considered to occur in the experimental group. The percentage of four misconceptions that are considered to occur in the experimental class is always smaller than the percentage of misconceptions in the controling class. It proves that the EMBE-R strategy is more effective in preventing CE misconceptions than the verification strategy.

The cultivation of appropriate prerequisite concepts such as the mole concept, reaction rate, exothermic, and endothermic in the modification stage makes it easy for students to form a complete understanding of the concept of CE and prevent misconceptions. For example, understanding the exact concept where the number of moles of a substance in the reaction equation is proportional to the reaction coefficient can prevent misconceptions on the concept of the effect of volume changes on the gas equilibrium system. A proper understanding of the concept reaction rate can avoid misunderstandings about the equilibrium state and dynamic equilibrium. Adequate knowledge of the concept of exothermic and endothermic reactions can prevent misconceptions about the concept of temperature changes effect on gas equilibrium system. Optimizing the inquiry questions at the concept building stage from teacher and through the worksheet can facilitate student's SRA development. Students with high SRA are less likely to experience misconceptions and can be more easily to understand concepts because they have the ability to think about correlation, combination, and deductived hypothetical (Lawson, 2004).

The inquiry learning process can make students be active in the class, help students learn in a fun way, and help them gain depth about their concepts (Zubaidah *et al.*, 2017). Besides, it provides an opportunity for students to find ideas in making their concepts based on concepts that have been previously (Pedaste *et al.*, 2015). Another advantage of the EMBE-R strategy is that students can work together in small groups to complete the questions on their worksheets to make it easier to build an understanding of concepts. Discussion activities between students in groups and other groups in class discussions, and completing exercises in student worksheets can strengthen understanding of CE concepts.

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Relevant research by Eymur & Geban (2017) that cooperative learning is accompanied by conceptual changes to the prevalence of chemical misconceptions and can improve student's conceptual understanding. The concept validation process supports activity at each stage in the EMBE-R strategy. Concept validation is intended to check whether student's knowledge of CE material concepts is correct or misconceptions have been successfully prevented.

Conclusion and recommendation

The EMBE-R strategy is more effective in preventing misconceptions than the verification strategy. The number of student misconceptions in the experimental group was smaller than the controlling group at high and low SRA levels. The strengths of applying the EMBER strategy are: (1) increasing the proper understanding of CE prerequisite concepts; (2) stimulating the development of students SRA by maximizing inquiry questions; (3) improving student's knowledge of ideas about the interrelation of macroscopic, submicroscopic, and symbolic representations, by maximizing animated media in learning; (4) increasing understanding conceptual on the CE concept by validating student understanding at each stage to avoid misconceptions.

Besides, cooperative learning arrangements will enhance collaboration between students and build trust through discussion. Thus, constructing concepts becomes more accessible, more meaningful, and achieve a proper understanding of CE prerequisite concepts. Understanding the appropriate prerequisite concepts can facilitate connections with new conceptual understanding. A proper understanding will increase the SRA and prevent misconceptions. The EMBE-R strategy can improve the idea of knowledge at high and low SRA levels. It can be seen that the average number of student's misconceptions taught with the EMBE-R strategy at high and low SRA levels are three and four, respectively. While the verification strategy, the number of student's misconceptions at both levels was eight misconceptions. Students with high SRA levels find it easier to understand concepts because they already have high-level thinking skills, such as reasoning, proporting, variables controlling, probabling, challenging, and hypotheses deducting. Thus, students can analyze and choose concepts that are more reasonable and appropriate for themselves.

The limitation of this study is that student's SRA tested only after learning. Further research could be done as an improvement by giving the SRA test before and after implementation of the EMBE-R strategy. Thus, testing the effectiveness of this strategy to develop SRA can be a complement to this research.

Future research in the application of the EMBE-R strategy is recommended to prevent misconceptions about other topics in chemistry.

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