Chemistry students’ cognitive structures in oxidation-reduction, through an 8E learning cycle

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Abstract. The purpose of this study was to analyse students’ cognitive structure in the concept of oxidation reduction by employing an 8E learning cycle model. 32 students in year-10 were participated in the study. Data was collected by a drawing and writing technique demonstrated through student worksheets, interviews, observations, and a reflective journal. The 8E learning cycle, which consist of engage, explore, e-search, elaborate, exchange, extend, evaluate and explain stages, was applied to the process. Data analysis consisted of data reduction, data presentation, and a conclusion. Students’ cognitive structures were divided into three categories, namely; an understanding, misconception and no understanding. Categories of understanding were found in the concept of redox, oxidizing agents and acid-base nomenclature, and transitions. Students’ misconceptions of categories were found in the redox applications and polyatomic. Students faced challenges in understanding the oxidation number and binary nomenclature. The results show that misconceptions were decreased through the implementation of the 8E learning cycle. The 8E Learning cycle also has implications for students’ critical thinking, collaboration, and empathy communication skills.

1. Introduction

Cognitive structures can help describe students understanding of concepts through their thinking [1-3]. They show the process of thinking before and after the learning process [4]. Students’ incorrect pre-knowledge can complicate understanding of concepts and lead to misconceptions [5]. Student understanding shows a combination of concepts that are based on three chemistry representations, start from the sub-microscopic level [6]. Chemistry is described in three representations [7]: (1) macroscopic representations that describe the properties that are related to phenomena in our daily lives (for example, colour change, solution pH, gas formation, and precipitation in chemical reactions); (2) sub-microscopic representations that provide an explanation at the atomic level where material is explained as an arrangement of atoms, molecules or ions; and (3) symbolic representations which describe chemical symbols, formulas and equations.

Chemistry is considered a difficult subject involving fundamental abstract concepts [8], such as decomposition, particle properties of a substance, and chemical bonding [9]. Most of the research on understanding oxidation-reduction reactions has focused on students' difficulties in identifying oxidation-reduction reactions [10]. The causes of these difficulties appear to lie with chemistry teachers and the textbooks they use that often have more than one definition for oxidation and reduction processes.
This study was conducted based on the difficulties students had in understanding the oxidation-reduction concept and the use of a learning model that is not able for improving students’ conceptual understanding.

A learning cycle is a model that uses a constructivist approach [12] and focuses on students learning concepts deeply, and applying the solutions in their daily lives [13]. Through this approach, students develop their own concepts and adapt them to new situations by utilizing their previous experience and prior knowledge [14]. Teachers can give students meaningful activities in this model [15]. In the study, the 8E learning cycle was employed to develop students’ understanding through conflict cognitive, knowledge construction, and collaboration [16]. In this research, students’ understanding in oxidation-reduction concepts was explored through analysing their cognitive structure in chemistry learning by employing the 8E learning cycle. Students’ understanding of the concepts were explored to identify the influence of the 8E learning cycle on students’ conceptual development in oxidation-reduction concepts. This learning cycle was used to analyze students’ cognitive structures at each step of the learning activities so that the teacher could address students’ misconceptions.

2. Methods
The study employed a qualitative method with data collection of interview, reflective journal, students’ worksheet and drawing-writing technique. Students' cognitive structures on redox material and nomenclature was analysed by data reduction, data display, and verification/conclusion [17]. During the eight steps, students completed the worksheet and drawing-writing technique which showed their structure cognitive development. The interview was conducted after the lessons, meanwhile the observation and reflective journal was conducted during the lesson.

Learning cycle 8E was started by giving study case to students to stimulate their critical thinking. They completed the worksheet by using their prior knowledge, internet or other sources, have discussion group, and at the evaluation stage teacher give feedbacks and direction on students’ conceptual understanding. The worksheet was employed to capture students structure cognitive throughout the phases as the Figure 1 display below.

![Figure 1. Learning cycle 8E.](Image)

The first step is Engage that started by giving a case study of oxidation reduction learning on daily life events to stimulate students’ prior knowledge. The next step is Explore which students wrote their prior knowledge about the oxidation number in the case study using writing drawing technique. In the E-search stage, students looked for information about redox from various sources, especially the internet, both from articles, e-books or the web. At Elaborate stage, after searching for learning resources,
students elaborated their prior knowledge with knowledge obtained from various learning sources and wrote it on their worksheets.

Students worked in groups and share opinions at the Exchange stage and continue with the Extend stage where students rewrite the knowledge they have obtained based on the group discussion. The teacher explored students thinking after steps and explained the concepts to evaluate their knowledge in the Evaluate stage. The final stage, students need to explain their understanding by wrote their final conceptual understanding which have been obtained from all 8E learning cycle stages. The cognitive structure of students is taken from the four stages (wrote on worksheet) of Explore, Elaborate, Extend and Explain by using drawing-writing technique.

Interview was held to deep understand the results of their drawing-writing in the 8E learning cycle process. Drawing-writing technique is a method which students are asked to do drawing activities along with writing explanation. Students can express what is not easily written into words: indescribable, difficult to understand [18]. The results of this drawing-writing that written or illustrated by students were data which then analyzed as students' conceptual understanding together with other data collection results by categorizing with understanding, misconception, and no understanding.

3. Result and discussion
The result shows that students' understanding developed from Explore until Explain stage while the no understanding category showed a decrease from the beginning until the last stage of Learning Cycle 8E. This cognitive structure of oxidation-reduction concept displays in Figure 2 below.

![Figure 2. Students’ understanding on oxidation-reduction concept.](image)

Based on the picture above, it can be seen that the percentage of students' understanding of oxidation-reduction concepts were changed at each stage. Changes from the Explore to Elaborate stage showed an increase in students' understanding from the beginning, where there was no understanding, to where 69% of students who understood. The data was collected and analysed based on a drawing-writing technique that was verified by interview. One of drawing-writing technique samples below shows that student 02 can draw the oxidation-reduction application used in daily life. Based on Figure 3 below, student 02 understands that oxidation and reduction reactions occur separately, not simultaneously. The processes of reduction and oxidation cannot occur in separate circumstances, but it is one reaction [19]. Reduction is a process when the oxidation number decreases, and electrons are on the left side from the half reaction and vice versa [20]. So, student 02 has a misconception based on this data.
Figure 3. Student 02’s drawing-writing.

Figure 4 below shows that student 06, at the Elaborate stage can write his understanding on the student worksheet regarding reduction and oxidation reactions. This student’s understanding of the concept of oxidation reduction reactions is still limited in terms of the understanding of electrons and oxygen. Based on Student 06’s understanding, an oxidation number is a number given to other elements when they form a molecule. However, this understanding is still not complete because the student described oxidation numbers but did not relate it to the oxygen and electrons concept as well as what the student described in the concept of oxidation reduction. The following statements show, student 02 and 21 explain oxidation and reduction based on the oxygen and electron concept.

"The oxidation reaction happens when oxygen release from a substance, while the reduction is combining substances from oxygen. The oxidation number is the oxygen charge in the reaction. " (Students 02, January 27, 2017)

"Oxidation is the reaction of releasing oxygen for compounds" (Student 21, January 27, 2017)

The results of the interview above show that in the Explore stage, students are categorized as no understanding and have misconceptions. Many students were also confused in writing answers on the student worksheet. However, based on the results of the following interview, student 21 could explain the oxidation number.

"The number is Fe^{3+}, the oxidation number is 3^+." Student 21, January 27, 2017)

The oxidation number of atoms in ionic forms is equal with the ion charge [20]. Iron from the statement above is in the form of ions and students can mention the oxidation number of the iron ion, so student 21 is categorized as understand.
Student 06 at the Explain stage also shows that he has understood the concept of oxidation and autoredox reactions which can be seen from the following interview transcript:

**Teacher**: How do you feel after today’s learning?

**Student 06**: I know the definitions of oxidation-reduction, oxidation number and autoredox.

**Teacher**: From all the stages, which stage do you like the most?

**Student 06**: After you explained, I know the theories better

**Teacher**: After you searched, have discussion and explained by the teacher, what do you know about the oxidation-reduction reaction?

**Student 06**: Oxidation is the binding of oxygen and releasing electrons. While reduction is binding electrons and releasing oxygen.

**Teacher**: How do you know if a compound has oxidation and reduction?

**Student 06**: Through reducing and oxidising agents. I mean, we set the reducing agent first, so the reducing agent is reducing other substances but itself undergo an oxidation reaction. (Students 06, 3 February 2017)

Student 06 has understood the concepts of reductor and oxidator and used this concept in determining which compounds undergo oxidation and reduction. The students’ understanding of a reducing agent is appropriate with the existing theory. Substances that give electrons are called reducing agents whereas substances that accept electrons are called oxidizing agents [19].

**Teacher**: Can you give examples of compounds that undergo oxidation?

**Student 06**: Substance with Cl oh... NaCl

**Teacher**: Which one releases electrons?

**Student 06**: I think Na that releases electrons, and Cl who received electrons

**Teacher**: What is an oxidator?

**Student 06**: The substance who oxidizes other substances but itself undergoes reduction

**Teacher**: What is meant by auto-redox?

**Student 06**: If the redox reaction, the reducing and oxidising agents are different, while in the autoredox, they are from the same compound. (Students 06, 3 February 2017)

The interview transcript shows that student 06 has been able to give examples of compounds that undergo redox reactions based on the theory of the release and receive electrons, but is still hesitant in determining which substances release electrons. When asked about auto-redox, student 06 was able to distinguish it from redox reactions.

The 8E Learning cycle is informed by constructivist theory where students construct their own knowledge rather than obtaining it from another. The theory is student-centered and describes the nature of knowledge and how information is understood [21]. Based on the data, the 8E Learning cycle impacts on students’ critical thinking, collaboration, and communication skills which are aspects of character development and aligned with the current Curriculum 2013 pedagogical approach [22]. Many students preferred the case study at the Engage stage compared to other stages, as evidenced by the results of the following interview:

"I really like case studies; we were given the opportunity to write answers by ourselves based on what we think." (Student 21, January 27, 2017)

Students like to answer the study case based on what they think, and this pre-knowledge can lead them to think critically to solve problems at the Engage stage. Critical thinking skills that could be developed in this study are (a) knowing the problem, (b) finding the solution, and (c) collecting and arranging the information needed [23]. In the Exchange stage, students could share their opinions which helped develop their communication and collaboration skills on how they worked together to get the best ideas or answers and how they appreciated other’s ideas in the group. In this forum, the teacher acts as the facilitator, monitoring the discussion and providing direction on the worksheet.
4. Conclusion
The 8E Learning cycle model can help develop students conceptual understanding by exploring their cognitive structures which can be explored in the four stages of Explore, Elaborate, Extend and Explain. The results that were obtained from students’ understandings show the number of students who understood from the explore stage to the explain stage increased on the oxidation-reduction concept.

This learning model also improve students’ skills by stimulating critical thinking skills at the engage stage and developing communication skills and empathy at exchange stage during group discussion.

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