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SURVEY OF HIGH SCHOOL STUDENTS' UNDERSTANDING OF OXIDATION-REDUCTION REACTION

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Abstract. *This study investigated the conceptions of 340 Taiwanese high school students (grades 10 to 12) regarding oxidation–reduction reactions. The diagnostic tool used was a two-tier test based on a concept map of redox reactions as presented in high school curriculums. The reliability of the two-tier test items was 0.82. The results show that most 11th graders performed equally well in questions related to the concept of the gain and loss of electrons during oxidation–reduction. In terms of working with oxidation numbers, scores increased with grade level. The results of this study provide valuable reference for curriculum designers and science instructors.*

Key words: *concept map, oxidation–reduction, redox, two-tier.*

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Introduction

Accurately measuring levels of student understanding is an important element of science education. Numerous studies around the world have examined student conceptions of science (Chang et al., 2007; Chi & Roscoe, 2002; Lin & Chiu, 2010). Novak, Gowin, and Johansen (1983) findings on the function of concept maps in North American high school classrooms show that learning outcomes in the school chemistry lab were significantly improved with the assistance of concept maps. They further found that the use of concept maps reduced the amount of formal instruction required by advanced chemistry students. McClary and Bretz (2012) suggested that chemistry teachers carefully examine the comprehensiveness of their instruction to assist their students in further integrating the concepts learnt in the class (Bratennikova & Vasilevskaya, 2002).

This study had two aims: 1) to study the conceptions that Taiwanese students in Grades 10, 11, and 12 hold with regard to oxidation–reduction and how they are able to apply what they have learnt; and 2) to propose a concept map of redox reactions for the high school curriculum. We also compared the learning achievements of students who have different conceptualizations of chemistry-related subjects.

This study used the two-tier diagnostic tool developed by Treagust (1988, 1995), which has been widely used to investigate student conceptions in many areas of science education, including chemistry, biology, and physics (Chiu, 2007; Odom & Barrow, 1995; Tan, Goh, Chia, & Treagust, 2002; Wang, Chiu, Lin, & Chou, 2013). The two-tier test is typically of a multiple-choice format, with the first tier containing a knowledge statement and the second presenting reasons for the choice made in the first tier. This method helps to promote higher order thinking and to identify misconceptions held by the students. The latter can help the researcher to understand their mental processes regarding chemistry and thereby construct an accurate concept map which can be used to further learning.

Theoretical Background

Evaluating Conceptual Development via Two-tier Diagnostic Testing

Conceptual development can be evaluated using open-ended written tests, word association methods, group tests of the demonstration type, demonstration observation, clinical interviews, case interviews, event interviews, and two-tier tests (Ogan-Bekiroglu, 2007). These methods of evaluation each have their merits and drawbacks (Bromley, Irwin-DeVitis, & Modlo, 1995; Moon, Hoffman, Novak, & Cañas, 2011). The questions for first and second tiers for multiple respondents provide more options and the data they generate cannot be analysed which often leads to an excessive number of correct answers. However, the same questions for a single respondent lead to simpler analysis because there are more answers. In comparison, this type of two-tier question enables one to judge whether the respondent has answered the question correctly.

To ensure that the diagnostic tool covers all the course topics under study and all the concepts in the relevant concept map, it is necessary to review evaluations of the concepts, interview students, and formulate effective questions (Treagust et al., 2011). The tool must be continually developed and improved by those applying it so that it is tailored to suit the needs of the students.

Concept Maps in Chemistry Education

Novak et al. (1983) was the first to popularise the idea of concept maps. They are graphical learning tools built on the principles of progressive differentiation and integration. Novak et al. (1983) defined a concept as a perceived regularity in an event or object, which can be represented using words or symbols. A concept map then is a graphical representation of the sources and relationships among various concepts (Novak, 1977; Novak & Gowin, 1984). Concept maps are a simple but effective teaching tool.

However, it can be difficult to follow an intuitive representation of ideas within a strict curriculum. The structure of a concept map must communicate what is going on in teacher's head with the mental workings of the students in order to reduce confusion and misunderstanding. Novak and Gowin (1984) demonstrated how researchers can successfully use concept maps at any level to investigate learning achievement, attitudes toward learning, and concept change in relation to elementary science studies. Using these graphical representations of cognitive processes, researchers and educators can easily identify and correct student misconceptions and misconstructions, thereby helping students to improve their performance in learning (Novak, 2010).

Methodology of Research

The purpose of this study was to explore the conceptual development of high school students with regard to oxidation–reduction reactions. We collected qualitative data through a two-tier diagnostic test that combined qualitative and quantitative approaches. Students answered both multiple choice and open-ended questions. We surveyed classes in which some of the students successfully demonstrated the proper process for oxidation-reduction. Collecting both qualitative and quantitative data not only helps the researcher to see whether the students understand the concepts they have been taught but also their actual problem solving skills without the teacher's assistance. The process through which the two-tier test was developed will be explained in further detail below.

Pilot Study

The two-tier diagnostic test was a combination of qualitative and quantitative approach which contains a semi-open ended pre-test for 122 student participants. Subsequently, the students' common alternative concepts of the oxidation–reduction relative concepts were analyzed. Analysis of the results showed that the discrimination index ranged from 0.35 to 0.88 and the difficulty index had an average of 0.45. Questions with discrimination indexes of less than 0.30 were removed. The data obtained from the pre-test were analyzed and compared, and were used to correct and develop the two-tier multiple-choice questions. In addition, a test was administered to a selected sample of students to explore students' preconceptions; this written test was used to select students for further interviewing.

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Participants

This study selected 340 high school students from multiple grade levels to conduct formative assessments related to oxidation–reduction. The participants were 96 students in Grade 10, 99 students in Grade 11, and 145 students in Grade 12.

Two-tier Test

Two-tier tests are easy to evaluate and score objectively but also offer some insight into higher level thinking. In order to develop our two-tier test, course content was first clearly defined. A concept map representing this content was then developed. Collecting information about students' concepts via reviewing can help researchers develop appropriate multiple-choice questions. We therefore conducted unstructured student interviews to gain a wider perspective of their understanding. We then categorized and analysed the interview results to identify answer patterns that corresponded to the students' mental models. Two university chemistry professors developed the two-tier assessment according to these answer patterns (please see the Appendix). A high school chemistry instructor (who possesses a Ph.D. in chemistry) then verified the validity of the assessment and made modifications as will be discussed in the following sections. In cases where the first part of the question was answered correctly but the second was answered incorrectly, partial credit was given. This is in accordance with the suggestions of (Odom & Barrow, 1995; Treagust, 1988, 1995).

Test Validity and Reliability

The test included 12 problems and 32 questions. The discrimination index ranged from 0.34 to 0.77, with an average of 0.58. The difficulty index ranged from 0.28 to 0.66, with an average of 0.47. Reliability was high: Cronbach's *α* value for internal consistency, based on SPSS 17.0 calculations, was 0.82.

Analysis supported the high construct validity of the two-tier diagnostic tool. The average difficulty and average index of discrimination of the two-tier diagnostic tool were 0.45 and 0.48, respectively.

Semi-structured Interviews

Students' interviews were used to assist interpretation of the results of this study. According to Lin and Chiu (2010), there are three performance groups (high, medium and low performance) suitable for two-tier analysis. Therefore, following analysis of the test results, 12 students representing an even distribution among high-, medium-, and low-learning achievement in the two-tier diagnostic test were selected to participate in a half-hour formal interview. Random sampling was used. After students agreed to take part in the interview, consent was also sought from their parents. The following questions formed the basis of the interview:

1. The following are a few common chemical reactions. Can you identify which is an oxidation reaction? Which is a reduction reaction? Which is a redox reaction? Please explain your reasoning.
   Magnesium ribbon combustion: $2Mg + O_2 \rightarrow 2MgO$
   Copper wire in a silver nitrate solution: $Cu_{(s)} + 2\ Ag^{+}{}_{(aq)} \rightarrow Cu^{2+}{}_{(aq)} + 2Ag_{(s)}$
   Photosynthesis: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + \text{Energy}$
   Copper combustion in chlorine: $Cu + Cl_2 \rightarrow CuCl_2$
   Zinc-copper battery reaction mechanism: $Zn \rightarrow Zn^{2+} + 2e^-$
   $Cu^{2+} + 2e^- \rightarrow Cu$
   Iron smelting: $2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$
2. Can oxidation reactions and reduction reactions occur independently? Please explain your reasoning.
3. Identify the oxidant and reductant of the reaction equation presented in the first question. How have you determined this?
4. Can you explain the concept of an oxidation number?
5. Express the oxidation numbers of the elements in the following reaction equation:
   $Cu(s) + Ag^{+}{}_{(aq)} \rightarrow Cu^{2+}{}_{(aq)} + Ag_{(s)}$
   (The reaction is not balanced)

These questions were arrived at after analysis of individual test results and discussions with experts and scholars.

Results of Research

Overall Performance of Each Grade in Questions on Redox Reactions

Student performance differed with grade level. 10th graders on average answered 6.4 questions correctly, 11th graders 7.5 questions and 12th graders 9.2 questions. This trend indicates that the number of correct answers increases in accordance with education level. Based on average scores, significant differences existed between 10th and 11th graders and 10th and 12th graders, but not between 11th and 12th graders.

Table 1 shows the performance of students in answering questions related to the redox concept. Students from Grade 12 had the best scores, followed by the Grade 11 students, and lastly, the Grade 10 students. As shown in Table 2, an analysis of variance (ANOVA) of the grand average of the test results showed substantial differences among the groups. Significant differences were found between results of students from Grades 10 and 11, and between students from Grades 10 and 12. Table 3 presents the differences for the number of correct answers on redox test.

Table 1. Grand mean of the number of correct answers on the redox test (32 questions).

	Numbers of students	Average number of correct answers	Standard deviation
10th grade	96	10.31	4.42
11th grade	99	17.21	6.56
12th grade	145	18.30	7.65

Table 2. ANOVA of redox test scores.

Source of variation	SS	df	MS	F	p
Inter-group	3990.14	2	1995.07	46.34	0.000
Intra-group	14509.42	337	43.06		
Total for all groups	18499.56	339			

The p value was less than 0.05, indicating significant differences among the groups. The statistical package used reported a value of p=0.000 when the p value was lower than the threshold.

Most of the students performed well in answering questions on the concept of gain and loss of oxygen in the oxidation–reduction reaction, and their performance improved with grade level. The 11th grade school students performed slightly better than the 12th grade students, although the differences were not statistically significant. The 12th grade students obtained higher scores for the questions on the definition of the oxidation number and its application, and these scores increased with grade level.

Table 3. Grand mean differences for the number of correct answers on redox test.

Grade (I)	Grade (J)	Difference for the mean	Standard error	p
10th grade	11th grade	−6.90*	0.94	0.000**
	12th grade	−7.98*	0.86	0.000**
11th grade	10th grade	6.90*	0.94	0.000**
	12th grade	−1.08	0.86	0.449
12th grade	10th grade	7.98*	0.86	0.000**
	11th grade	1.08	0.86	0.449

***p < 0.05 indicates a significant difference.*

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The above table shows that 11th and 12th graders answered 63.4% of the questions correctly followed by the 11th graders. 30% of the students answered questions 1 and 2 incorrectly. It was rare for all three grades to answer all of the questions wrong. We postulate that the 10th graders did not perform significantly worse than 11th and 12th graders because the basic theories and concepts of redox reaction are covered in Grade 10. Some 11th graders outperformed the 12th graders and this might be because the 12th graders had since studied a unit on electrochemistry. It is very easy to confuse this theory with redox reaction theory.

This research analyzes the individual performances of three grades of students based on the two-tiered examination tests. The research subjects include 10th graders, 11th graders and 12th graders. Considering it is very rare for the 10th graders to come across electron transfer (an important knowledge in battery) and oxidation state, the author reduces the number of oxidation state-relevant questions in order to obtain a balanced scoring. Moreover, 12th graders have learned about the electron transfer at the end of the second semester in their 12th grade. Therefore, they have more experience in the relevant theories and concepts which is why the sample is chosen from the 11th graders to investigate the understanding of electron transfer in redox reaction.

Therefore, it can be said that 12th graders have better understanding and performance in concept map related questions than the 11th and 10th graders do. As for the questions 5-6 and 11-12 concerning the gain and loss of electrons, 11th graders score the best (9.9 questions on average), followed by 12th graders (8.8 questions on average) and 10th graders (5.4 questions on average). The aforementioned results also contain testing of application of concept map in two-tier questions with multiple choices which leads the author to speculate that 11th graders have a more ingrained grasp of it. All in all, based on the scoring in question 5-6 and 11-12, it can be said that there is a significant difference between 10th graders and 11th graders, 10th graders and 12th graders. In sum, 11th graders have significantly better performance than the 10th graders while sharing no significant difference with the 12th graders.

Student Performance on Concept Maps

This study examined the results of students at various learning levels to distinguish between the conceptual differences of pre-existing knowledge and given knowledge. In Figure 1 we present a concept map which was developed after compiling concept maps produced by students in the high achievement group. These students possessed knowledge regarding oxygen atoms, electrons, and oxidation numbers, and successfully connected these knowledge nodes by using connectives related to the oxygen atom (gain/discard), electrons (gain/loss), and oxidation number (increase/decrease).

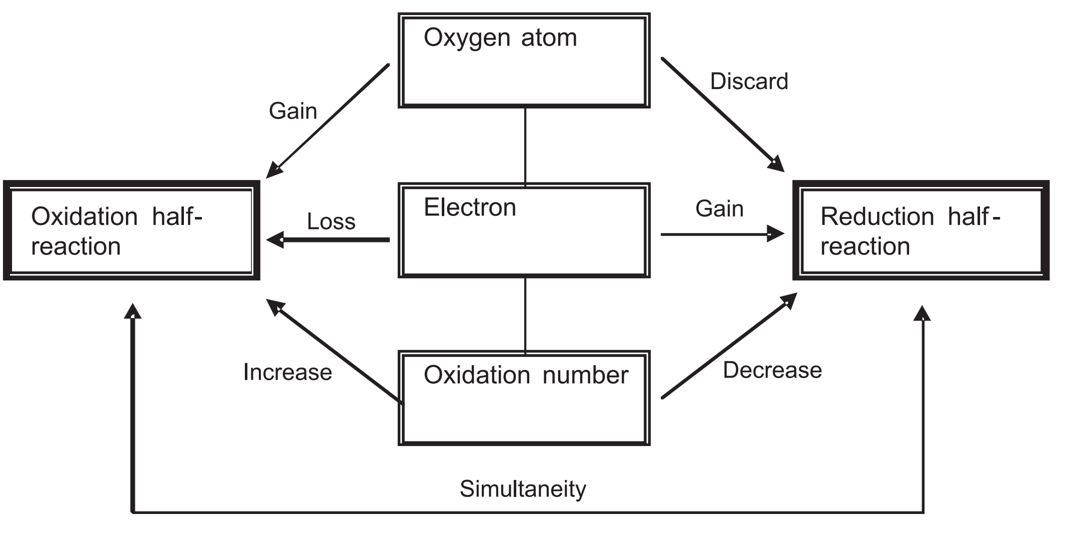

Figure 1: Concept map for the high-achievement group.

As shown in Figures 1 & 2, students from the middle- and high-achievement groups were unable to answer the questions regarding the gain and loss of electrons and the change in the oxidation number, indicating that they had not formed knowledge connections in this area. The figure also shows that after concept maps were introduced, the groups did not show explicit differences, however, the learning attitude improved in the low-achievement group. The low-achievement group possesses little processional knowledge in chemistry classes. It shows that concept map is more a mental tool rather than a practical one as different students hold distinctive ideas about whether it can help them achieve higher scores in chemistry classes. The high-achievement group appears to have achieved better performance on the tests their, because they used the concept maps more.

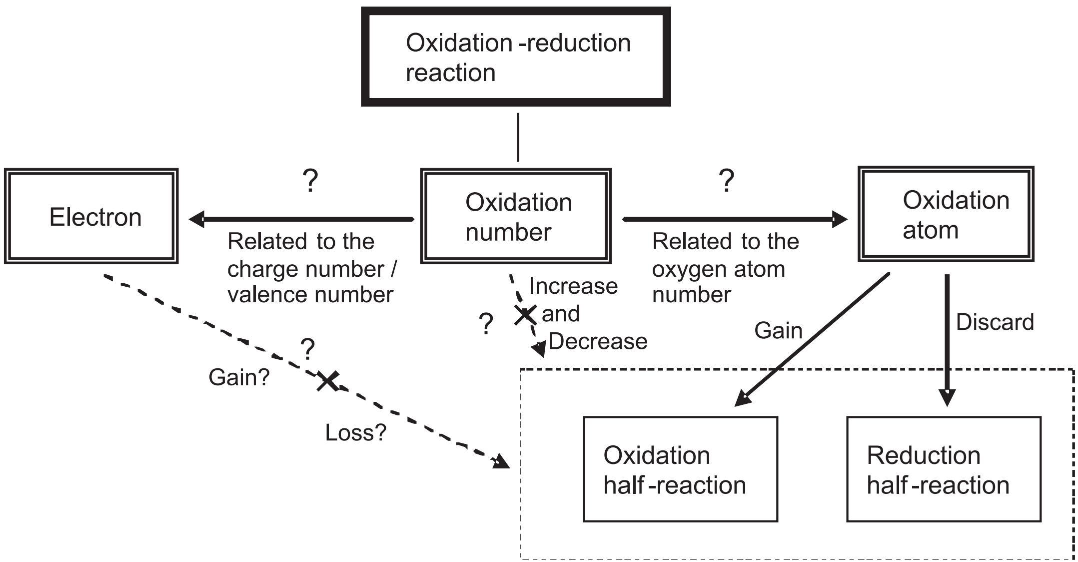

Figure 2: Concept map for the middle-achievement group.

11th graders tended to make mistakes in the questions involving concept maps. For example, in question 3-6, the correct answer rate was 45% with the 12th graders scoring the highest followed by the 11th graders and 10th graders. As the grade ascends the performance in questions of concept maps improves. Also, this shows that the probability of answering the questions correctly will be increased as the grades of students increased (diSessa, 2002).

12th graders (the high-achievement group) score the highest as their curriculum covers working theories of electrical batteries, but they still tend to make mistakes on questions 5-10, which were related to electrolysis and electroplating. An important indication suggested by this analysis is that the concept of redox reaction is useful in assessing students' grasp of basic chemistry knowledge. For example, in the 36 questions designed to investigate their understanding of general knowledge related to oxidation, students' choices reflect their mental models. One of their mental models is to rely on a certain vague memory to confirm their perception. Furthermore, Questions 7-12 contain advanced materials as well as some of the basic concepts. Questions 2-4 and 5-9 are especially effective in examining 11th and 12th graders' ability to apply basic oxidation knowledge to solve complicated problems. In oxidation state questions, 12th graders reported finding it easy to apply the theory they have learnt. This indicates that the scientific mental model, which involves rational thinking, is the most commonly used. By contrast, when 12th graders are solving oxidation state and basic knowledge application questions, the most common mental model is combustion and decomposition models. The students claimed they could have performed better than the 11th graders if each combination could be remembered.

As shown in Figure 3, the low-achievement group mostly used connectives to represent their knowledge of oxidation-reduction. However, it turns out they had false associations regarding the oxidation–reduction reaction when the number of oxygen atoms was miscalculated. This indicates among 11th graders there is a lack of basic knowledge regarding electrons and oxidation numbers.

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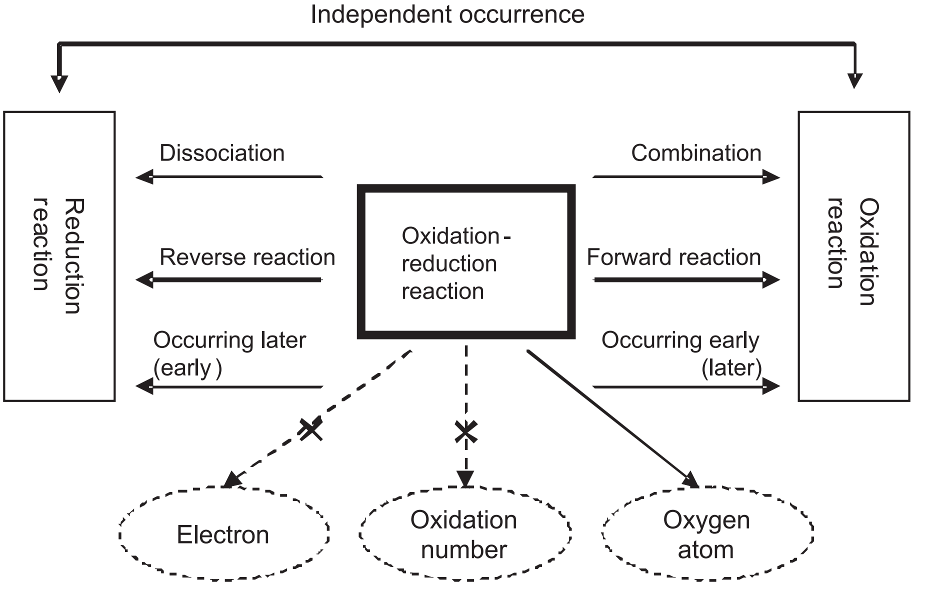

Figure 3: Concept map for the low-achievement group.

Discussion

Based on our results, we divided the sample of students into high, medium and low levels of understanding related to redox reactions. As far as the concept of redox reaction itself, the low-achievement group of students responded poorly in questions regarding the working mechanisms of various redox phenomenon. For example, some 11th graders mixed up the process of a redox reaction. Some 11th graders answered question 11 incorrectly because they thought that the redox reaction is concerned with reaction and substances. Their mistakes can be attributed to their insufficient ability to observe the essence of the micro world. While most low-achievement students could memorize knowledge related to reactions, a large number of them were not able to apply the necessary concepts in the test. This indicates that the composite mental model is not the most effective.

The medium-achievement group appeared to have memorized the different concepts related to redox and applied their knowledge correctly to some degree. For example, they could correctly categorize the given elements. Moreover, their perception of chemical reactions is consistent with their understanding as represented by their concept maps. Therefore, a scientific mental model could come into play while they were answering the two-tiered test. In other words, the medium-achievement group of students could use scientific reasoning to solve the problems. Most of the medium-achievement students would choose to consider the reaction between the different factors on a micro level. In combustion questions, they tended to think that the reaction was irrelevant to the change in oxidation state and this therefore did not represent a redox reaction. This mistake can be attributed to misconceptions related to oxidation states based on incorrect substance categorization.

In the high-achievement group, the students could reproduce almost all the redox definitions and concepts and use them in different types of questions. For example, they were able to recognize the consistency in the reactions that involve particles and electrons. The three groups of students displayed different conceptual knowledge and, in answering questions regarding redox reactions, they followed different paths to solve the problem at hand. The high-achievement group typically applied a scientific model from the beginning to end of their problem-solving process. In comparison, the medium-achievement group tended to follow a slightly varied pattern (scientific model combined with oxidation state model or the electron model). The low-achievement group followed a distinctively composite pattern that at times involved almost all of the concepts represented in the concept map.

In terms of applying oxidation state rules to solve chemistry problems, the three groups also exhibited different approaches. The high-achievement group could recall small details which they successfully combined with overarching theory. The medium-achievement group tended to hold on doggedly to the theory which at times inhibited successful application of what they had learnt. The low-achievement group tended to be confused about various basic concepts.

Conclusions

Effectiveness of Two-tiered Testing

In general, the students selected for this study performed well in questions related to oxygen-loss and oxygen-gain redox reactions. As the grade level increased, students started to perform better in general knowledge (although this difference was not statistically significant) and in particular on questions related to the loss and gain of electrons and to application of theory. Although a third of the tenth graders believed that redox reactions involved the loss of oxygen, they could not accurately explain the phenomenon using redox theory. They tended to believe that oxidation involves the loss of oxygen, and reduction the gain of oxygen. In different situations, their explanations regarding the gain or loss of oxygen contradicted each other. A very large number of the 11th and 12th graders could correctly explain the gain and loss of electrons. Although the differences between the grades were not significant, it is assumed that twelfth graders perform better in explaining the dynamic process of redox reactions using the gain and loss of electrons than eleventh graders do. Most students in all three grades believed that the processes of redox reactions occur simultaneously. Therefore, successful learning of the correct sequence requires considerable improvement in the understanding of tenth graders. Theories regarding the gain and loss of oxygen, electron transfer, and the gain and loss of redox states have been proven to be extremely challenging to students in general. These abstract and hard-to-observe phenomena are difficult both in conceptualization and application. More often than not, students resort to memorizing rigid rules in order to get good grades (Kolomuç & Çalık, 2012). Although the textbooks are designed according to evaluations of students' interpretative ability and learning capacity, the selection of appropriate theories is still a challenging task for textbook creators as they must necessarily contain highly abstract knowledge the students have never encountered before (Lin & Chiu, 2010). This generally leads to students interpreting the micro concepts they see in the books using macro phenomena (Suchocki, 2013).

Therefore, the presentation of the multiple theory model needs to be thoroughly explained by the teachers. It is also necessary to introduce wide-range thinking to maintain consistency in theories and applications (McClary & Talanquer, 2011). In this way, the textbook-based learning of redox reaction can be made more systematic and effective for students.

Implications

Curriculum Design

Through in-depth interviews, we found evidence that students who were misinformed about basic concepts or definitions tended to make incorrect inferences extending from these misconceptions. In accordance with the suggestions of de Jong, Acampo, and Verdonk (1995), it is recommended that teachers seek to understand students' mental processes with regard to electron transfer and thereafter design a curriculum that enables students to clarify previously-learnt concepts through experiment, discussion, creative thinking, and situational adjustment. In this way, students should be able to successfully integrate new concepts into their knowledge structures.

Certain limitations of two-tier diagnostic testing became apparent during the research. The first is that it cannot be applied to solve practical problems in students' learning, especially when the problems happen in a specific context. The second is that it cannot be used to evaluate the integration rate of information and knowledge learnt in class. As far as science teachers are concerned, although the two-tier tests can help to measure students' understanding, they are not of great use when it comes to retaining knowledge as students advance into higher grades.

Science teachers commonly teach redox reactions by introducing it through a verbal definition and assigning various concepts for the students to memorize, such as 'loss of electrons is associated with oxidation'. Although this kind of rote learning has its place, starting with memorization drills tends to reduce the students' interest in going further with the topic (Kurbanoglu, 2013). Teachers are encouraged to include the discussion of the two-tiered tests concerning the loss and gain in electrons and redox states. Lawson and Renner (1975) suggested that for classes of advanced students, more difficult concepts such as the balance of redox reactions and self-oxidation-reduction reactions can be introduced. McClary and Bretz (2012) suggested that science teachers introduce redox reactions by introducing a variety of redox reaction experiments using real-life materials such as hair and light bulbs. In this way, the students will come to understand that there are many redox reactions happening all around them. This will contribute to helping students cultivate the habit of scientific observation in their everyday lives.

Recommendations for Future Study

The participants for the interviews were selected based on the results of their performance in the two-tier test and the sample therefore does not follow normal distribution. This restricts the reliability of the end results. If future research conducted a study of a larger scale, wherein the sample was representative of a specific region or nation, the results would be more representative of the current trends in this field.

The participants exhibited different levels of understanding regarding the facts and application of redox reactions. While all had completed the basic curriculum related to redox reactions, they were in different phases of the curriculum. For example, some students had already moved on to electrochemistry. This lead to gaps in the collected data . Therefore, in order to avoid this inconsistency, further studies might design a study of increased duration. If researchers could track changes in terms of mental models, concept maps and performance of the students, the process of learning chemistry could be more comprehensively analysed.

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Appendix: Sample Questions from Two-tier Diagnostic Test

Bleach water is an effective household cleaner used to kill bacteria, fungi, and viruses. It was extensively used when Taiwan experienced a SARS outbreak. It sterilizes through the following reaction:

$ClO^{-}_{(aq)}$ (Hypochlorite) + $2I^{-}_{(aq)}$ (Iodide) + $2H^{+}_{(aq)}$ → $I_{2(aq)}$ (Iodine) + $H_2O_{(l)}$ + $Cl^{-}_{(aq)}$ (Chloride ion)

( ) Does this reaction equation involve the electron transfer process?

Yes (2) No

( ) Please state the reason for your answer.

Yes (A) I^- loses an electron and becomes I_2, whereas chloride ion in ClO^- gains an electron and becomes Cl^-. The electron transfers when the oxidation–reduction reaction occurs. (B) ClO^- combines with H^+ to form H_2O, which is electrically neutral. This step involves an electron transfer. Therefore, this reaction is not an oxidation–reduction reaction. (C) Before and after the reaction, the total charge number changes, which can only result from the gain and loss of electrons. (D) After ClO^- removes the oxygen atom and loses an electron, it forms Cl^-. Therefore, electron transfer occurs in the reaction.
No (E) ClO^-(hypochlorite) first reacts with I^-, slowly generating H_2O which is electrically neutral. (F) The reaction is a simple combination and dissociation of ionic compounds. (G) After ClO^- and I^- generate I_2 in an acidic environment, the reaction ends if there is no electron transfer. (H) Before and after the reaction, the oxygen numbers of the Cl and I atoms are the same, indicating no electron transfer. (I) Before and after the reaction, the atom number does not change and the electron number is conserved. (J) The sterilizing principles of the disinfectant fluid do not include combustion and heat, which are not part of the oxidation–reduction reaction. Therefore, there is no electron transfer.

Edison invented the light bulb to enable us to see in the dark. A lamp is typically used in light bulbs, which contain volatile gases at high temperatures. By adding iodine and gaseous tungsten to react with the iodine molecules, we cause the lamp to light up.

The reaction equation is as shown below:

W (tungsten) + I_2 (Iodine) → WI_{2} (tungsten(II) iodide)

( ) What type of chemical reaction is this?

(1) Only an oxidation reaction (2) Only a reduction action

(3) Oxidation–reduction reaction (4) Not an oxidation–reduction reaction

( ) Please state the reason for your answer.

Only an oxidation reaction (A) The light bulb has a high temperature, and the light and heat involves the participation of oxygen. Therefore, it is an oxidation reaction. (B) The oxygen in the air reacts with the metal W and gaseous iodine, thus it is an oxidation reaction.

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Only a reduction reaction
(C) WI_2 restores and separates the W (tungsten). Therefore, it is a reduction reaction.
(D) In the process of the reaction, W in WI_2 decomposes. The reaction ends immediately and only a simple reduction reaction occurs.

Oxidation–reduction reaction
(E) The oxidation number of W increases as it becomes part of the compound WI_2. At this point, the oxidation number decreases when WI_2 reacts to produce gaseous iodine. Therefore, this reaction is an oxidation–reduction reaction.
(F) W gains an electron and I_2 loses an electron because the reaction of I_2 involves the gain and loss of an electron. Therefore, it is an oxidation–reduction reaction.
(G) The oxygen in the air participates in the reaction, generating an oxidation product that loses oxygen. Therefore, it is an oxidation–reduction reaction.
(H) The oxygen does not participate in the reaction. Therefore, it is not an oxidation–reduction reaction.
(I) No material loses or gains electrons during the reaction. Therefore, it is not an oxidation–reduction reaction.
(J) The reaction is only the combination of W and I_2. Therefore, it is an oxidation–reduction reaction.
(K) The reaction does not involve a change of the oxidation number. Therefore, it is not an oxidation–reduction reaction.

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