# Using an Activity Worksheet to Remediate Students' Alternative Conceptions of Metallic Bonding

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## Abstract

*This study describes the development of an activity worksheet for remediating Year 9 students' (aged 13 to 14 years old) misconceptions of metallic bonding. The worksheet was designed using the Instruction Design Model (Reiser&Dick,1996) and implemented after the administration of the two-tiered Diagnostic Test of Metallic Bonding. Students' conceptions of metallic bonding before and after the activities using the worksheet are reported. Statistical analysis was performed on the data to identify students' conceptions (correct, alternative or incorrect) of metallic bonding, and assess the effectiveness of the activity worksheet, the Worksheet on Metallic Bonding (WMB), in remediating students' misconceptions of metallic bonding. The paired sample t-test showed that there was a significance change in students' conceptions of the nature of metallic bonding, and the electrical conductivity of metals after using the activity worksheet.*

**Keywords:** metallic bonding; alternative conception, instructional design, conceptual change, diagnostic test; activity worksheet

## *Introduction*

Traditionally in a teacher-centred classroom, the teacher introduced science concepts to students by explaining the theories at the start of the lessons. Eliciting students' prior knowledge, mind capture and scaffolding questions are rarely observed in the lessons. In such classrooms, students' prior knowledge is not challenged as they are not given the opportunity to discuss their ideas with peers and the teacher. Smith, Blakeslee and Anderson (1993) suggested that a process of learning science in a meaningful way brought about conceptual change that required the learner to realign, reorganise, or replace existing alternative conceptions in order to accommodate new ideas. Harrison and Treagust (2001) suggested that the extent to which students can accommodate scientific conceptions will be based upon those who have the ability to replace their alternative conceptions with the accurate scientific conceptions. For these alternative conceptions to be remediated, a cognitive conflict needs to be implemented in lessons (Driver, Asoko, Leach, Mortimer & Scott, 1994).

Thus, in order for conceptual change to occur, science teachers need to create lessons where students can express their own concepts and allow them to have their concepts being challenged with the accepted scientific views. In order to engage students in discussion, teachers need to facilitate a learning environment where students can freely articulate their concepts without the 'fear of ridicule' (Hewson, 1992). Science teachers also need to reduce the level of teacher – talk and increased the level of 'student-talk in a lesson (Pope & Gilbert, 1985). Mind capture or a series of demonstration of the concept at the start of the lesson could be implemented. This approach can lead the way for students to explain the phenomena of the concept and in turn establish a student-centred learning environment. In addition, this can foster students' understanding of the concepts and prevent them from memorising chemical equations and regurgitating what they memorise into their examination (Chandrasegaran, Treagust & Mocerino, 2009).

A substantial number of researchers studied the use of effective strategies in promoting conceptual change in chemistry education. Some research studies reported that conceptual understanding in students could be enhanced through the use of effective strategies such as multiple levels of representation, cooperative learning, inquiry-type practical work and the use of ICT. The following highlights studies that use these strategies to promote conceptual change in science and chemistry education.

*Multiple levels of representation.* The multiple levels of representation in chemistry are the macroscopic, submicroscopic and symbolic levels. When students do not understand the inter-connectedness between those levels, they encounter difficulties in comprehending the concepts. As a result, students resort to memorisation instead of understanding wholly the underlying concepts. Vast volumes of studies (e.g. Gilbert &Treagust, 2009) have contributed in facilitating student learning by integrating different strategic instructions in chemistry education. Chandrasegaran et al. (2009) studied on Grade 9 students in Singapore where an instruction of multiple levels of representation for the concept on chemical reactions was develop and implemented. The instruction consisted of small group discussions, highlighting the importance of coefficients and subscripts, laboratory activities and inferring ionic equations. Students in the instruction of multiple levels of representation performed better, confirming that their understanding of the levels of representation was improved.

*Cooperative learning*. Cooperative learning promotes active participation from the teacher and student, and among the students themselves. This type of approach initiated a positive influence as thinking and communication skills are developed, discussion of knowledge and ideas take place, and promotes teamwork (Sisovic & Bojovic, 2000). Basili and Sanford (1991) conducted an experimental research on college students learning the laws of conservation of matter and nature, and the particulate nature of solids, liquids and gases. In the study, the students were placed in small cooperative group to allow them to discussed and elicit their alternative conceptions. It was found that although many of the students still held alternative conceptions on the two concepts, the experimental groups' alternative conceptions were significantly lower than the control groups.

Acar and Tarhan (2007) examined the effectiveness of cooperative learning instruction of forty-one Grade 11 students on their understanding of electrochemistry. The lesson that used cooperative learning consisted of various activities such as brainstorming, practical experiment, computer animation and group discussion. The results from the pre- and post-test and interviews with students, revealed that students in the experimental groups (i.e. cooperative learning group) achieved better scores in the test and, managed to rectified their alternative conceptions that they held previously in their pre-test.

*Inquiry-type practical work.* Practical work in a laboratory is a central approach for many teachers to carry out in their lessons. Applying practical work in lesson promotes meaningful learning because students would be aware of what and how the concept is as they are performing hands-on activities. Also, this would dissipate students' idea of learning science as being dull. The implementation of practical experiments in an inquiry-type lesson provides a base for students to discover and engage in problem-solving discussion. Besides this, students can also attain and develop many skills such as psychomotor skills, inquiry and scientific skills and improve in their collaborative skills when they discuss with one another(Hofstein, 2004). Hofstein, Nahum and Shore (2001) indicated that students favoured learning in an environment that consisted of laboratory because they were more involved in learning through being able to have the freedom in designing their experiment, interpreting and coming up with a conclusion. Inquiry-type experiments promote students to ask better scientific questions which could contribute on their understanding of science (Hoftstein, Shore &Kipnis, 2004).

*The use of ICT*. The use of ICT comprised of animation, video, multimedia, web-based learning and simulation. The use of ICT in a science lesson provides many benefits to the teaching and learning through developing high-quality mental models and enhancing students' conceptual understanding (Pekdağ, 2010). ICT allows students to explore and obtain visual feedback immediately. For instance, students can visualise abstract concepts such as models of atoms, molecules and bonds through animation and simulation. Research studies have showed that learning a concept through just practical experiments is difficult because students are unable to comprehend why the concept take place.ICT in lessons can improve students' investigative skills through practical activities and, the use of simulation provides a virtual option to actual practical (McFarlene&Sakellariou, 2002).

Burke, Greenbowe and Windschitl (1998) claimed that students could associate the levels of representation that are the microscopic, macroscopic and symbolic areas, better with the use of animation in their chemistry demonstration classes. The authors implemented a computer animation on the standard hydrogen electrode of the concept of electrochemistry, which is one of the abstract concepts students found difficulty in learning. Sanger and Greenbowe (2000) studied 135 college students on the effects of viewing computer animations and obtaining conceptual change strategies of the current flow in aqueous solution. It was found from their study that there was a significant difference in regards to the interaction between the use of animations and conceptual change instruction. In addition, experimental students performed better in their post-test scores than the control students.

Morgil, Yavuz, Oskay&Arda (2005), also showed that there was a significant difference from the experimental group using computer-assisted learning on acids and bases. Their post-test scores showed a better improvement than the control groups. In the current study, a Worksheet for Metallic Bonding (WMB) was designed for the teachers as a guide to promote conceptual change in their lesson. The WMB consists of activities that incorporate animation, video and practical work with scaffolding questions based on the Bloom's Taxonomy. The WMB was designed using Instructional Design Model (Reiser& Dick, 1996).

**Research Design**

A quantitative research approach for this study involved the administration of a two-tiered diagnostic multiple-choice test before and after lessons using the Worksheet on Metallic Bonding. Data were gathered to identify the conceptions and alternative conceptions of Year 9 students before and after lesson on metallic bonding were conducted. Cross-tabulation and paired-sample t-test was employed on the data to provide statistical evidence and support for answering the research questions.

**Purpose of the Study**

While many research studies on metallic bonding have been focused on identification of alternative conceptions, studies on the strategy used to remediate or prevent alternative conceptions on metallic bonding have been limited. The main purpose of this research is to identify students' conceptions of metallic bonding and to investigate the effectiveness of using a Worksheet of Metallic Bonding as a teaching strategy in changing students' misconception. Specifically, the research addressed the following three research questions.

1. Is there any relationship between students' conception and reasoning for the concepts of metallic bonding before and after the lessons using the Worksheet of Metallic Bonding (WMB)?
2. What are Year 9 students' conceptions of metallic bonding before and after lessons using the Worksheet of Metallic Bonding (WMB)?
3. How do Year 9 students' conceptions of metallic bonding change after using the Worksheet on Metallic Bonding?

**Subjects**

The sample comprised of 42 Chemistry Year 9 students (aged 13-16 years old) from three secondary schools located in the urban areas. Year 9 students were chosen because the topic of Chemical bonding was taught at this level. There were a total of three groups of students selected for this study. Table 2 shows the distribution of students participants in the project. The students from Teacher A class consisted of 9 male students. A total of five male students and ten female students were from Teacher B's class. Lastly, thirteen male students and five female students were from Teacher C's class.

Teacher A had a bachelor degree in General Science Education, Teacher B had a Bachelor degree in Science Education, and Teacher C had a Master's degree in Science Education. Teacher A has been teaching for six years, Teacher B has only been teaching for over two years while Teacher C has been teaching for sixteen years.

**Table 2: Number of Students by Gender and Group**

| Gender | Group | | | Total |
|---|---|---|---|---|
| | Whole class (Teacher A) | Small group-discussion (Teacher B) | Combination of whole class and small group discussion (Teacher C) | |
| Male | 9 | 5 | 13 | 27 |
| Female | 0 | 10 | 5 | 15 |
| Total | 9 | 15 | 18 | 42 |

**Table 1: Common alternative conceptions related to metallic bonding**

| Alternative conceptions |
|---|
| *Definition of metallic bonding* |
| Metallic bonding is weak bonding. [1] |
| There is no bonding in metals[2] |
| There is some form of bonding in metals, but not proper bonding[2] |
| Metals have metallic bonding, which is a sea of electrons[2]. |
| Molecular iodine is metallic in nature. [1] |
| Metallic lattices contain neutral atoms. [1] |
| The bonding in metals is a type of ionic bonding.[3] |
| Metallic bonding occurs with electron sharing, so metallic bond is the same with covalent bonding.[3] |
| Metallic bonding looks like ionic bonding. Valence electrons of one metal atom are attacked by the others nuclei and ionic bonds occur between electrons and nucleus.[3] |
| Continuous metallic or ionic lattices are molecular in nature.[1] |
| The charged species in metallic lattices are nuclei rather than ions. [1] |
| Electrons are negative charged particles and they act as negative ions. [3] |
| *Electrical conductivity, melting and boiling point* |
| There is ionic bonding between metal atoms, because ionic compounds have good electrical conductivity.[3] |
| Metals have positive and negative ions and so, they conduct electricity. [3] |
| Because of ionic characteristic of metal, they have high melting and boiling points like ionic compounds.[3] |
| Electrons, which surround positive charged atoms, push the other free electrons and thus metals conduct electric and heat.[3] |
| *Malleability of metals* |
| Metals, which are malleable, hold together with weak forces.[3] |
| If metals are hammered, some or the positive charged atoms getaway from that point and some of them are crushed. [3] |

Source: [1]Coll & Taylor (2001); [2]Taber (2003); [3]Acar&Tarhan (2008)

**Development of the Worksheet on Metallic Bonding**

The development of the Worksheet of Metallic Bonding (WMB) was based on the Instruction Design Model (Reiser& Dick, 1996), which involved a series of steps (see Figure 1). Identifying the instructional goals and objectives were the first two initial steps. Planning the instructional activities, and choosing instructional media followed these initial steps.The final two steps were development of the assessment tools, and implement instruction.

The goals and objectives of the WMB were focused on students' achievement of the correct conceptions of the nature of metallic bonding, and electrical conductivity of metals, which were drawn from a list of alternative conceptions of metallic bonding held by Year 9 students (aged 13 to 14) compiled from various literatures (see Table 1). Next, the teaching and learning (T&L) activities were planned, and instruction media were searched online and in textbooks. From these activities, a series of scaffolding questions were produced to be included in the lesson plan and also in the worksheets. Two separate worksheets were developed i.e. one for the teacher and the other for the student, which consisted of four activities and could be implemented in a one and a half hour lesson.

**Identify instructional goals** ⇨ **Identify Objectives** ⇨ **Plan Instructional Activities** ⇨ **Choose Instructional Media** ⇨ **Developing Assessment Tools** ⇨ **Implement Instruction**

**Figure 1. Instruction Design Model (Reiser& Dick, 1996)**

The WMB consisted of four activities. Both teacher and student worksheets were the same except that the teacher's worksheet included a mind capture. In the teacher's worksheet, a mind capture to instigate students' prior knowledge of metals was included.

For example, a photograph of rubber insulated copper wires was shown to students. Using the photograph, scaffolding questions were asked to lead students to contemplate on what type of bonding copper has.

The second activity was an animation showing positive ions surrounded by delocalised electrons was shown. After the animation was shown, students were put into teams, which would allow them to collaborate and discuss their answers in the worksheet. The questions in the student worksheet elicited students' prior knowledge for example, the concept of states of matter. Clues were given at the end of some questions to elicit students' understanding.

The third activity was a practical activity on metallic bonding. The practical activity served as a scaffold for students to formulate a hypothesis, identify the objective, list out control variables, design an experimental procedure, draw the equipment set-up from their hypotheses and procedures to perform the experiment, record their observations, deduce a conclusion and confirm or refute their hypotheses.

The fourth activity consisted of an animation and a video. The first was an animation, which explained how metals conduct electricity. Students could use the information from the animation and discussed among themselves. The second was a video showing malleability in metals that illustrated why metals are malleable. A question on the application of malleability relating to real-life situation was asked.

The objectives of the WMB included all of the three learning domains of Bloom's Taxonomy, which are cognitive, psychomotor and affective domain. It allowed less teacher talk and more inquiry learning among students. The worksheet was edited and verified by the head of the project before being presented to the teachers. Therefore, this worksheet could provide the teachers with ample time to improve on their lesson plans prior to the enactment of their metallic bonding lesson. The development of the assessment tool, the two-tiered Diagnostic Test of Metallic Bonding is described next. For final stage of the model, the implement instruction is incorporated in the WMB.

**Instrument: Two-tiered Diagnostic Test on Metallic Bonding**

There are many methods used to identify students' understanding and misconceptions of science concepts; such as concept mapping (Taber, 1994; Nicoll, Franscisco and Nakhleh, 2001; Uzuntiryaki & Geban, 2005; Özmen, Demircioğlu & Coll, 2009), word association (Chiu, Chou & Liu, 2002; Hovardas&Korfiatis, 2006), interviews about instances and events (Osbourne& Gilbert, 1980; Watts, 1981; Nicoll, 2001; Harrison &Treagust, 2001; Taber, 2003; Coll&Treagust, 2003), multiple-choice questions (Taber, 1997), open-ended question (Harrison &Treagust, 2000; Barker & Millar, 2000), free essay (Harrison &Treagust, 2000) and drawings (Boo, 1998; Harrison &Treagust, 2000; Nicoll, 2001; Coll& Taylor, 2001).

One of the effective ways to probe students' ideas of a concept is through interviews (Osborne & Gilbert, 1980; Watts, 1981; Harrison &Treagust, 2001; Taber, 2003). Interviews provide thorough information in ascertaining students' conceptions. However, there were drawbacks in administering interviews as they are time consuming and required substantial training for teachers to conduct interviews (Treagust, 1988). Treagust (1988) developed of a two-tier diagnostic test to identify students' understanding of the science concept in the first tier, and their explanation of their conceptions in the second tier.

The present study developed a two-tiered diagnostic tests on metallic bonding adapted and modified from the multiple choice items in Metallic Bonding Concept Test developed by Acar&Tarhan, 2008, but were modified into two-tiered diagnostic items. Table 3 shows the items that had been designed to investigate students' understanding of the nature of metallic bonding and the electrical conductivity of metals. The items on metallic bonding are part of a larger study on students' conception of bonding and are extracted for the purpose of writing this paper.

**Table 3: The Two-Tiered Diagnostic Items of Metallic Bonding Designed for this Study**

| Item | Response (Tier I) | | Reasoning (Tier II) |
|---|---|---|---|
| The elements in iron are held together by metallic bonding. | **(A)True** | (B) False | A. Metallic lattices contain neutral atoms.<br>B. Continuous metallic or ionic lattices are molecular.<br>C. Metal to non-metal bonding in alloys is electrostatic.<br>**D. Metals are electropositive elements held together by valence electrons** |
| Metals are good conductors of electricity because they | (A)form ionic bonds<br>**(B)contain mobile electrons** | | A. Ionic compounds have good electrical conductivity.<br>**B. Metals have positive ions in a 'sea of electrons'**<br>C. Electrons flow from positive and negative ions.<br>D. Electrons are negative charged particles. |

*The bold statement represents the correct conception and reasoning*

## Results

*Students' Conceptions of Metallic Bonding*

This section presents the results of statistical analysis that provides answers to the first research question: Is there any relationship between students' conception and reasoning for the concept of metallic bonding before and after the lessons?

Statistical analysis using cross-tabulation of students' conceptions of metallic bonding and their reasoning in terms of their selections of combination of answers was performed. Statistical significance of Pearson Chi-square statistic and its inferences will also be discussed. For several of the statistical analyses, Fisher's Exact Probability Test was used when the lowest expected frequency in any cell should be 5 or more (Pallant, 2005). A cross-tabulation was performed in order to determine the statistical significance in the relationship between students' conception and reasoning. The relationship of their conceptions and reasoning for each items presented in the DTMB can be determined through Pearson Chi-square. The purpose for a cross tabulation was to categorise students' conceptions and to find out if the students in this study acquired the correct conceptions of the concepts of chemical bonding through actual understanding of the concepts and not by randomly selecting the choice of answers.

For the purpose of analyses, the data from the DTMB used in this study were analysed in two steps. In the first step, the percentage of students who responded by selecting the correct or incorrect choice from the metallic bonding items in the DTMB were analysed. For each item in the diagnostic test, students were required to select response from a two-tier multiple-choice that consisted of Tier I (conception), and Tier II (reasoning). After selecting their choice for Tier I, students were required to select one out of four choices, in Tier II for the reasoning to the conception.

**Table4: Types of Correct Conception and Alternative Conceptions Identified**

| Category of conception | Choice for Tier I | Choice for Tier II |
|---|---|---|
| Category 1 (Correct conception) | Correct conception | Correct reasoning |
| Category 2 (Alternative conception) | Correct conception | Incorrect reasoning |
| Category 3 (Alternative conception) | Incorrect conception | Correct reasoning |
| Category 4 (Incorrect conception) | Incorrect conception | Incorrect reasoning |

Table 4 illustrates the combination of answers that students could select in the DTMB. In Category 1, students selected both correct responses for the conception and the reasoning. This indicated that students held correct conception on chemical bonding. In Category 2 students selected the correct response in Tier I but an incorrect choice for Tier II. This indicated that overall students held the alternative conception as they held the correct conception but incorrect reasoning. In Category 3, students selected the wrong choice in Tier I but selected the correct choice in Tier II. This indicated overall students held an alternative conception as they held the wrong conception but correct reasoning. Finally for Category 4, students selected for both tiers the incorrect choice, which suggested that they did not hold the correct conception and reasoning. In summary, Category I represented the correct conceptions. Category II and III represented the alternative conceptions while Category IV represents the incorrect conceptions.

From Table 5, it can be observed that before the lesson on metallic bonding using the WMB, less than half of the students were in Category 1 (correct conception and correct reasoning) for the concept of nature of metallic bonding (41.5%). However, only two per cent (2.4%) of students were in Category 1 for the concept of electrical conductivity of metals. After the lessons on metallic bonding using the worksheet, there was an increase of percentage of students in Category 1 for both concepts i.e. the nature of metallic bonding (from 41.5% to 58.5%) and electrical conductivity (from 2.4% to 32.5%).

There were students who were in Category 2 and 3 who held alternative conceptions on metallic bonding. For example, more than a third of the students held correct conception but wrong reasoning on the concept of nature of metallic bonding (34.1%). Also, more than a quarter of students were in Category 2 for electrical conductivity of metals (26.8%). After the lessons, there was an increase in the percentage of students in Category 2 for the nature of metallic bonding (from 34.1% to 39.0%). However, it can be seen from Table 5 that about a small number of students (27.5%) still held alternative conceptions (incorrect conception but correct reasoning, Category 3) on the concept of electrical conductivity of metals after the lesson using the WMB.

Generally before the lessons on metallic bonding, a large percentage of students (68.3%) were in Category 4(incorrect conception and incorrect reasoning) for the concept of electrical conductivity of metals. However after the lessons, there was a decrease in percentage of students for both concepts on metallic bonding, which were nature of metallic bonding (from 68.3% to 2.4%), and electrical conductivity (from 68.3% to 27.5%).

**Table 5: Total Distribution of Students' Conceptions of Metallic Bonding (N = 42) Before and After Lessonsusing WMB**

| Metallic bonding | Concepts | Item no. | Category of conception | | | |
|---|---|---|---|---|---|---|
| | | | Category 1 | Category 2 | Category 3 | Category 4 |
| | | | 100% | 100% | 100% | 100% |
| *Response* Before Lessons | Nature of metallic bonding | 1&2 | 41.5%(17) | 34.1%(14) | 2.4%(1) | 22.0%(9) |
| | Electrical conductivity of metals | 3&4 | 2.4%(1) | 26.8%(11) | 2.4%(1) | 68.3%(28) |
| *Response* After Lessons | Nature of metallic bonding | 1&2 | 58.5% (24) | 39.0% (16) | 0.0%(0) | 2.4%(1) |
| | Electrical conductivity of metals | 3&4 | 32.5% (13) | 12.5% (5) | 27.5% (11) | 27.5%(11) |

In summary, about forty-two per cent of students had the correct conception and correct reasoning (Category 1) of the nature of metallic bonding. The percentage of students who held the correct conception of the nature of metallic bonding increased to more than half of the students after the lessons. It is evident that students held alternative conceptions of the nature of metallic bonding before and after the lessons. A common alternative conception students held was that *metallic lattices contain neutral atoms*. Coll and Taylor (2001) reported that the alternative conception was due to confusion between the concept of ions with neutral species and nuclei in a metallic bonding. Table6 summarised students' correct conception and reasoning of the nature of metallic bonding and electrical conductivity of metals; and the prevalent common alternative conceptions still held by students after the lessons using WMB.

*Electrical conductivity of metals.*For the concept of electrical conductivity of metals, only two per cent of students have the correct conception and correct reasoning (Category 1) of the electrical conductivity of metals. The percentage of students who held the correct conception of the electrical conductivity of metals increased to almost one-third of the students.

**Table 6: Students' Conception of Metallic Bonding After the Lessons**

| Concepts | Correct response to Tier I of the item | Correct response to Tier II of the item | Prevalent alternative conception of the item |
|---|---|---|---|
| Nature of metallic bonding | The elements in iron are held together by metallic bonding. (*True*) | Metals are electropositive elements held together by valence electrons. | The elements in iron are held together by metallic bonding because metallic lattices contain neutral atoms (24.4%) |
| Electrical conductivity of metals | Metals are good conductors of electricity because they. (*Contain mobile electrons*) | Metals have positive ions in a 'sea of electrons'. | Metals are good conductors of electricity because they formed ionic bonds. This is because ionic compounds have good electrical conductivity (17.5%)<br><br>Metals are good conductors of electricity because they formed ionic bonds. This is because metals have positive ions in a 'sea of electrons' (27.5%) |

*Students' Conception of the Nature of Metallic Bonding.*

This section presents the results of statistical analysis that provides answers to the second research question: What are Year 9 students' conceptions of metallic bonding before and after lessons using the WMBwere conducted?

In Tier I of the Item1on of the DTMB, students were required to select a choice of *True* or *False* regarding the statement: *The elements in iron are held together by metallic bonding.* The students' selection of *True* as the correct response represented their correct conception of nature of metallic bonding. Alternatively, their selection of the incorrect choice of *False* indicates the wrong conception of nature of metallic bonding. Table 8 shows that many of the students before the lessons (75.6%) held the correct conception by selecting the correct conception choice as *True* that *The elements in iron are held together by metallic bonding*, whereas about twenty-four per cent of students selected the incorrect choice of *False*. There was an increase in the percentage of correct response after the lesson as a majority of students (97.6%) selected *True* as the correct choice while just two per cent (2.4%) selected the wrong choice of *False*.

In Tier II of the Item 2 of the DTMB, students were required to select from four choices of reasoning for their conception in Tier I(Item 1). The correct reason was Choice (IV): *Metals are electropositive elements held together by valence electrons*. The others are wrong choices: I (*Metallic lattices contain neutral atoms),* II (*Continuous metallic or ionic lattices are molecular*) and III (*Metal to non-metal bonding in alloys is electrostatic.*). The students' wrong selection of choice represented their wrong reasoning for the conception of the nature of metallic bonding.

**Table 7: Cross tabulation of item 1 and 2 students' conception (tier I) against reasoning (tier II) before and after lesson on nature of metallic bonding**

| Conception (Tier I) | | Reasoning (Tier II) | | | | Total (%) |
|---|---|---|---|---|---|---|
| | *Response Choice* | *I* | *II* | *III* | *IV* | |
| The elements in iron are held together by metallic bonding.<br><br>*Response* Before Lesson | | Metallic lattices contain neutral atoms | Continuous metallic or ionic lattices are molecular. | Metal to non-metal bonding in alloys is electrostatic. | Metals are electropositive elements held together by valence electrons. | Response to Tier I |
| | *True* | 9(22.0%) | 1(2.4%) | 4(9.8%) | 17(41.5%)* | 31(75.6%) |
| | *False* | 2(4.9%) | 3(7.3%) | 4(9.8%) | 1(2.4%) | 10(24.4%) |
| | Total | 11(26.8%) | 4(9.8%) | 8(19.5%) | 18(43.9%) | 41(100.0%) |
| *Response* | *True* | 10 (24.4%) | 4(9.8%) | 2(4.9%) | 24(58.5%)* | 40(97.6%) |
| After | *False* | 1(2.4.%) | 0(0.0%) | 0(0.0%) | 0(0.0%) | 1(2.4%) |
| Lesson | Total | 11(26.8%) | 4(9.8%) | 2(4.9%) | 24(58.5%) | 41(100.0%) |

Note: * indicate correct conception and reasoning

**Students' correct conception of the nature of metallic bonding (category 1)**

Table 7 shows that before the lessons on metallic bonding, a large percentage of the students (41.5%) held the correct conceptions that *The elements in iron are held together by metallic bonding* (Choice *True* in Tier I) because *metals are electropositive elements held together by valence electrons* (Choice IV in Tier II). After the lessons, the percentage of students holding the correct conception and reasoning (Category I) increased slightly to about 59% (58.5%).

**Students' alternative conception of the nature of metallic bonding**

However, a majority of students who indicated alternative conceptions by either selecting by either selecting correctly in Tier I (*True*) but did not select the correct reasoning in Tier II (Category 2), or incorrect choice in Tier I (*False*) but provided correct reasoning in Tier II (Category 3). Students in Category 2 had shown the correct conception *Metals are electropositive elements held together by valence electrons* (True). However, they provided the wrong reasoning as indicated by their wrong selections of choice in Tier II *viz*.

Choice I: *Metallic lattices contain neutral atoms*. There were 22.0% of students who held alternative conception of Category 2 before the lessons, and the percentage was increased to 24.4% after lessons on metallic bonding.

ChoiceII :*Continuous metallic or ionic lattices are molecular*. There were about two per cent of students (2.4%) who selected this choice before the lessons, but this percentage increased to nearly ten per cent (9.8%) after the lessons.

Choice III: *Metal to non-metal bonding in alloys is electrostatic*. There were 9.8% of students who held this alternative conception before the lessons, and the percentage decreased to 4.9% after the lessons.

For Category 3, students selected correct reasoning Choice IV (*Metals are electropositive elements held together by valence electrons)* but selected the wrong choice in Tier I as False. There were two per cent of students who chose this selection but there was none after the lessons.

In summary, more than two-fifth of students had the correct conception and correct reasoning (Category 1) of the nature of metallic bonding. The percentage of students who held the correct conception of the nature of metallic bonding increased to more than half of the students after the lessons

**Students' conceptions on electrical conductivity of metals**

In Tier I of the Item 3 of the DTMB, students were required to complete the statement: *Metals are good conductors of electricity because they ____;* by selecting a choice of either *form ionic bonds* or *contains mobile electrons*. The students' selection of *contains mobile electrons* as the correct response represented their correct conception of electrical conductivity of metals.

Alternatively, their selection of the incorrect choice of *form ionic bonds* indicates the wrong conception of electrical conductivity of metals. Table 8 shows that most of the students before lesson (70.7%) held the correct conception by selecting the correct choice of *Contain mobile electrons* that *Metals are good conductors of electricity because they* while 29.3% of students selected wrong choice of *Form ionic bonds*. Similarly after the lessons, a majority of students (55.0%) selected the correct choice of Contain mobile electrons while forty-five per cent of students select the wrong choice of *Form ionic bonds.*

In Tier II of the Item 4 of the DTMB, students were required to select from four choices of reasoning for their conception in Tier I(Item 3). The correct reason was Choice (II): *Metals have positive ions in a 'sea of electrons'*. The others are wrong choices: I (*Ionic compounds have good electrical conductivity),* III (*Electrons flow from positive and negative ions*) and IV (*Electrons are negative charged particles*). The students' wrong selection of choice represented their wrong reasoning for the conception of the electrical conductivity of metals.
*Students' Correct Conception of Electrical Conductivity of Metals (Category 1)*

Table 8 shows that before the lessons on metallic bonding, a small percentage of students (2.4%) held the correct conceptions that *Metals are good conductors of electricity because they* (Choice *Contain mobile electrons* in Tier I) because *Metals have positive ions in a 'sea of electrons'* (Choice II in Tier II). After the lessons, the percentage of students holding the correct conception and reasoning (Category I) increased to about 32.5% after the lessons.

**Students' alternative conceptions on electrical conductivity of metals**

However, a majority of students who indicated alternative conceptions by either selecting by either selecting correctly in Tier I (*contains mobile electrons*) but did not select the correct reasoning in Tier II (Category 2), or incorrect choice in Tier I (*Form ionic bonds*) but provided correct reasoning in Tier II (Category 3). Students in Category 2 had shown the correct conception *Metals are good conductors of electricity because they* (*Contain mobile electrons*). However, they provided the wrong reasoning as indicated by their wrong selections of choice in Tier II.

**Table 8. Cross Tabulation of Item 3 and 4 Students' Conception(Tier I) against Reasoning (Tier II) Before and After Lesson on Electrical Conductivity of Metals**

| Conception (Tier I) | | Reasoning (Tier II) | | | | Total (%) |
|---|---|---|---|---|---|---|
| | *Response Choice* | *I* | *II* | *III* | *IV* | |
| Metals are good conductors of electricity because they. | | Ionic compounds have good electrical conductivity. | Metals have positive ions in a 'sea of electrons'. | Electrons flow from positive and negative ions | Electrons are negative charged particles | Response to Tier I |
| *Response* Before Lesson | *Form ionic bonds* | 18(43.9%) | 1(2.4%) | 9(22.0%) | 1(2.4%) | 29(70.7%) |
| | *Contains mobile electrons* | 2(4.9%) | 1(2.4%)* | 6(14.6%) | 3(7.3%) | 12(29.3%) |
| | Total | 11(26.8%) | 4(9.8%) | 8(19.5%) | 4(9.8%) | 41(100.0%) |
| *Response* After Lesson | *Form ionic bonds* | 7(17.5%) | 11(27.5%) | 4(10.0%) | 0(0.00%) | 22(55.0%) |
| | *Contains mobile electrons* | 0(0.0%) | 13(32.5%)* | 3(7.5%) | 2(5.0%) | 18(45.0%) |
| | Total | 7(17.5%) | 24(60.0%) | 7(17.5%) | 2(5.0%) | 40(100.0%) |

Note: * indicate correct conception and reasoning

Choice I: *Ionic compounds have good electrical conductivity.* There were 4.9% of students who held alternative conception of Category 2 before the lessons, but there were none after the lessons.

ChoiceIII: *Electrons flow from positive and negative ions.* There were 14.6% of students who selected this choice before lesson and, the percentage decreased to 7.5% after the lessons.

Choice IV: *Electrons are negative charged particles.* There were 7.3% of students who chose this selection before the lessons, but the percentage decreased to 5.0% after the lessons.

For Category 3, students selected correct reasoning Choice II (*Metals have positive ions in a 'sea of electrons)* but selected the wrong choice in Tier I as *Form ionic bonds.* There were two per cent of students who chose this selection before the lesson but the percentage was increased to 27.5% after the lessons.

In summary, only two per cent of students have the correct conception and correct reasoning (Category 1) of the electrical conductivity of metals. The percentage of students who held the correct conception of the electrical conductivity of metals increased to almost one-third of the students.

**Effectiveness of the worksheet on metallic bonding**

The following findings sought to answer the third and final research questions: How do Year 9 students' conceptions of metallic bonding change after teaching and learning process using the Worksheet on Metallic Bonding?

The data collected from the DTMB were analysed using the *paired sample t-test* in the *SPSS* version 20.0 software. The mean values in *paired sample statistics* for the total of pre- and post scores were compared. Null hypothesis was postulated in order to test the significance in the differences of mean scores for each type of chemical bonding. The p-value was set at .05. If the t-value is significant at p<.05, the null hypothesis is rejected. However if the t-value is not significant at p<.05, the null hypothesis is accepted.

**Table 9. Means and t-values of Paired Differences for the Pre- and Post-Tests for Metallic bonding**

| Bonding/Tests | | Paired Differences | | | t | Sig. (2-tailed) |
|---|---|---|---|---|---|---|
| | | Mean scores | Mean Differences | Std. Deviation | | |
| Metallic | Post<br>Pre | 6.61<br>5.53 | 1.079 | 1.217 | 5.467 | *.000 |

Note: * significant at p<.05

A null hypothesis posits that there is no significance difference in students' conception of metallic bonding before and after lesson using the WMB was conducted. The results of paired sample *t*-test shown in Table 9 revealed that there is a significance difference between the pre and post-test mean score at p<.05 (*t* = 5.47, *p* = .000). This result verifies that the null hypothesis is rejected. The effect size effect size was *d*= .447, which indicates a large differences between pre- and post-test.

It can be concluded that the use of the WMB had a significant large effect in changing students' conception of metallic bonding on the concept of the nature of metallic bonding and electrical conductivity of metals.

## *Conclusions, Recommendations and Limitations*

The following conclusions are derived from the results. Firstly, many students held alternative conceptions on both the concepts of nature of metallic bonding and electrical conductivity of metals. This confirmed that students do have correct conceptions and alternative conceptions of science phenomena before and after the lessons (Peterson et al., 1989). Secondly, the use of activities that incorporated higher-order thinking into the lessons would remediate students' alternative conceptions. Thirdly, the alternative conceptions that were held by the Year 9 students in this study show similar patterns with the findings from the related literature on students' alternative conceptions.

It was noted that there were students who did not have the knowledge of the concepts but selected the correct reasoning. Students were also found more likely to select the correct choice in Tier I(conception part) but incorrect choice in Tier II (reasoning part). Fourthly, there was a statistical significant difference for students' mean scores of the diagnostic test on the concepts metallic bonding given before and after the lessons on the concepts which indicated the large effect of the worksheet of metallic bonding in remediating students' alternative conceptions.

Finally, the teaching and learning process which incorporated the Bloom's taxonomy and higher-order thinking activities as well as the use of the WMB during the metallic bonding lessons revealed that students obtained better understanding on the concepts of chemical bonding through those activities. The use of animation and videos also enhanced students' understanding and promote correct conceptions of metallic bonding.

***The Use of a Revised Two-Tiered Diagnostic Test and the Development of a Three-Tiered Chemical Bonding Diagnostic Tests***

The same study could be repeated with the use of a revised two-tiered diagnostic test that will be more suited or appropriate to the Year 9 students. For instance, the language used in the current study may have been too difficult for students to understand. In addition, teachers can identify their students' prior knowledge by using the diagnostic test instead of interviews. A lot of time and research are required for teachers to design and develop a two-tier diagnostic test for a topic to be taught. Therefore as an alternative solution, teachers may have to rely on future research to design and develop diagnostic test for more topics on Chemistry.

Future researchers could design and developed a three-tiered diagnostic test of chemical bonding which format is similar to a two-tiered diagnostic test but with an additional tier that assess students' confidence in their choice of answers for the previous two tiers. This enables researchers to distinguish whether the students chose their answers randomly or if they really understood the concept.

***The Use of Worksheet of Bonding (WMB) as a Framework for Other Topics in Chemistry***

The WMB was designed using the Instruction Design Model framework developed by Reiser& Dick (1996). WMB can be used as a guide and model for teachers and curriculum developers to design other activities that allow meaningful learning activities for chemistry. The WMB incorporates various activities such as mind capture, animation, video and practical activities. Teachers and curriculum developers can design lessons or worksheet for other topics in chemistry by replicating these activities, as well as incorporating several other activities and scaffolding questions. A variety of teaching methods should be integrated in classroom lessons so that students can be intuitive and critical thinkers.

The following discusses the limitation of the methodology that was used in the study.

***The Pre-and Post-Diagnostic Test of Metallic Bonding (DTMB)***

There were a few alterations that could be made for the items on DTMB. For instance, instead of the scientific terms 'mobile electrons', the item should have been 'free electrons' because the latter term was taught to the students thus they were more familiar with the 'free electrons' term. In addition, more items relating to metallic bonding should be designed and included in the DTMB to ensure that more data relating to students' conceptions of metallic bonding could be identified.

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