Using a Constructive Approach to Monitor the Development of Conceptual Understanding among science students in an Urban Secondary School in North Trinidad

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Abstract

The main purpose of this study was to monitor the development of conceptual understanding using the 5E Learning cycle in the topic reactivity of metals. Sixteen students in a form four integrated science class were taught by instruction based on the 5E Learning cycle. Pre- and post- concept maps were constructed by each student in every lesson taught, to monitor their understanding. A Summative Concept Achievement Test was administered at the end of the topic to assess students' understanding and also the results were compared with those of the concept maps to determine if any conceptual change occurred at the end of the unit of work. Students' perceptions of this teaching strategy was also investigated. Results indicated that the 5E Learning cycle did affect students' conceptual understanding in three of the lessons taught. However, students did display no conceptual change with respect to some of the concepts taught. The students expressed that the 5E Learning cycle did help in their understanding and learning through an engaging learning environment.

Keywords: 5E Learning cycle, Conceptual Understanding, Concept maps, Reactivity of metals, Student perceptions.

Acknowledgements

I would like to thank God who has made the completion of this study possible. Also, I would like to express my gratitude to my supervisor for her constructive criticism and valuable suggestions throughout the study.

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CCM: Conceptual Change Model

SCAT: Summative Concept Achievement Test

PRMS: Post Concept Maps

POMS: Post Concept Maps

Chapter 1

Introduction

1.0 Background:

"Learning science is a cumulative process and each new piece of information is added to what students already know about the topic at hand" (Ozmen, 2004, p.147). It is well known that students do not come to the classroom as 'blank slates' but bring with them preexisting conceptions about science "that interfere with [their] learning of correct scientific principles or concepts" (Ozmen, 2004, p.147).

For more than forty decades, research has been conducted on students' conceptions in science and how it relates to the teaching and learning of science. In science, chemistry is regarded as being a difficult subject. Reasons for this range from concepts being abstract in nature to difficulty in the use of the jargon used in chemistry. These reasons make is more difficult for students to understand chemistry related topics.

"[Misconceptions] play a large role in learning chemistry than simply producing inadequate explanations to questions. Students either consciously or subconsciously construct their concepts as explanations for the behaviour, properties, or theories they experience. They believe most of these explanations are correct because these explanations make sense in terms of their understanding of the behaviour of the world around them" (Mulford & Robinson, 2002, p.739). As a result, students find it difficult to accept new information learnt when it contradicts their concepts.

According to Tan & Koh (2010) pupils learning chemistry have to operate at three different levels: (a) macroscopic or functional and descriptive, (b) symbolic or representational, and (c) sub-microscopic. Hilbing & Barke (as cited in Barke, Hazari, & Yitburek, 2009) states that the primary barrier to understanding chemistry is not the existence of the three levels of representing matter. It is that chemistry introduction occurs predominantly on the most abstract level, the symbolic level.

At the functional and descriptive level, the pupils deal with what they can see and manipulate. On the other hand, equations, graphs, and chemical formula, at the representational level, are used to record and handle the functional and descriptive level. The observed chemical or physical phenomena are explained at the sub-microscopic level in terms of abstract concepts such as sub-atomic particles, atoms, and molecules. "Empirical studies have shown that learning [sub-microscopic] and symbolic representations are especially difficult for students because these representations are invisible and abstract while students' understanding of chemistry relies heavily on sensory information" (Wu, Krajcik, & Soloway, 2000).

Tan & Koh (2010) go on to say that sub-microscopic entities such as atoms, ions and molecules and their interactions cannot be seen, so pupils have to believe their teachers that such things do exist. Though the pupils have studied the basic concepts of the particulate model of matter, atoms and molecules in the lower secondary science programme, it is uncertain whether they have understood these concepts sufficiently to make sense of the more advanced concepts. "[Thus] the acquisition of knowledge by students without a clear understanding may be attributed to the confusion caused in having to deal simultaneously with the macroscopic [e.g. colour changes and the formation of gases], submicroscopic and symbolic words of chemistry" (Chandrasegaran, Treagust, & Mocerino, 2007, p.294). Gabel (as cited in Chandrasegaran et al., 2007, p.294) reinforces that having to deal with these three levels of representation simultaneously, learners generally experience difficulty in explaining chemical reactions.

On a global level, Taiwanese students were found to come to school with 'pre-held' ideas about certain science concepts which resulted in students having a poor conceptual and meaningful understanding of major scientific concepts (Chiu, Guo & Treagust, 2007). Studies done in USA have found that many students could not use chemical concepts to solve conceptual problems (Nakhleh & Mitchell, 1993). A study done in New Zealand even revealed that third year chemistry students at university level, all of whom obtained good grades in previous courses, showed to have a high incidence of misconceptions (Coll, 2008).

Marcelo Cabrol, the chief of the IDB (International Development Bank) in a numeracy seminar in 2010 stated that the Latin American and the Caribbean region is facing profound crisis in numeracy education (numeracy education includes "understanding of mathematical and scientific concepts…" (Valverde & Naslund –Hadley, 2010)). He went on to say that these students perform below students in OECD and East Asian countries on international standardized test. The region has recognized the importance of conceptual understanding in science but there is little research evidence in the region to provide basis for how this problem might be remediated especially in the chemistry classroom.

This study developed due to my experience in eight years of teaching Integrated Science, that science students at the CSEC level in form four and five at school X, perform poorly when taught the chemistry topic-reactivity in metals. Students usually display a poor understanding in the topic by giving inappropriate observations and explanations in laboratory exercises and by not using the science concepts and terms taught. Students usually use words such as 'big' reaction to indicate a violent/vigorous reaction; 'rot' and 'deteriorate' to describe rusting of iron and 'bubbles of gas' to indicate the evolution of hydrogen gas; and 'disappear' or 'dissolve' to describe the reaction of metals with acids.

This is supported from an examiner's report which states that "candidates' knowledge of the reaction of metals with acids…was very limited" (CXC, 2011). The report goes on to say that candidates use terms inappropriately for example students use terms such as, ‘rust’, ‘melt’ and ‘dissolve’ to describe the reaction of the metals with dilute sulphuric acid. The report says responses are frequently erroneous. They included responses such as ‘the reaction got hot’, ‘electricity was generated’, ‘the metals rusted’ and ‘it exploded’. The report made the recommendation that “scientific vocabulary must be used and emphasized in the teaching and learning of scientific concepts” (CXC, 2011). Students clearly show misconceptions in this topic and what compounds the problem is its abstract content. Even their memorization of the order of reactivity amongst metals proves to be futile in the learning and understanding of this topic. In another Caribbean examination report (CXC, 2012), examiners also stated that it was a challenge for candidates to explain the rusting of iron. They also made recommendations that “candidates should be encouraged to answer the questions using scientific terms” (CXC, 2012).

Chemical reactions of metals with other chemical substances will also be examined in this study. Metals and its reactivity usually involve chemical reactions. Students usually have difficulties understanding because these chemical reactions cannot be seen and according to Gabel (as cited in Chandrasegaran, Treagust, & Mocerino, 2011, p.14) in order for students to achieve a deeper understanding of the changes that occur during chemical reactions, students should be able to navigate back and forth between the macroscopic representational system, the submicroscopic representational system and the symbolic representational system.

In Singapore, there is a part of the chemistry curriculum which involves chemical reactions and requires students to consider the changes that occur at the particulate level or to explain the significance of the chemical and ionic equations for the relevant chemical reactions. As a result according to Tan, Goh & Treagust (as cited in Chandrasegaran, Treagust, &

Mocerino, 2011, p.14) students generally memorise the chemical equations and regurgitate them in tests and examinations.

Students also display misconceptions in metallic bonding. De Posada; Taber (as cited in Coll & Taylor, 2002, p.176) state that many students … have a poor understanding of the bonding in metals, seeing it as weak or in some measure inferior to other forms of bonding. A study conducted in New Zealand among high school students and undergraduates showed that few students possessed a clear mental model or were highly confused about metallic bonding. Some students used the formation of covalent bonds to explain this type of bonding.

In addition to the misconceptions and the abstract nature with respect to this topic, a traditional teaching strategy has been dominantly been used to deliver the content of this topic. Balci, Cakiroglud, & Tekkaya (2006) state that the teaching approach is important in science for promoting meaningful learning and eliminating misconceptions. Research studies have supported “the effectiveness of the learning cycle in encouraging students to think creatively and critically, facilitating a better understanding of scientific concepts” (Balci, Cakiroglud, & Tekkaya, 2006). “Science education researches have established that students’ alternative conceptions in science are very tenacious and that traditional instruction is not very effective in promoting conceptual understanding” (Artun & Costu, 2012, p.2).

According Madu & Amaechi (2012) during the learning cycle, students [learn] through their own actions and reactions by involving hand-on-activities. This allows them to explore new materials and phenomena which “raise questions and encourage them to seek answers. [Their] exploration involves collecting and analysing data [which allows] them to test the alternative conceptions” (Madu & Amaechi, 2012, p.179).

In an effort to promote conceptual understanding in a form four integrated science classroom, the 5E Learning cycle- a constructive approach- will be used to monitor and develop conceptual understanding and to remedy students' misconceptions.

1.1 Statement of the Problem:

Chemistry is usually abstract in nature and students often find it difficult conceptualizing, visualizing and using terms and language appropriately. "Such abstraction and difficulties lead to the development of [misconceptions] among students" (Hanson, Donkor Taale, & Antwi, 2011, p.42). In addition, they often come to the classroom with their own conceptions which are sometimes different from that of the scientific community. The combined effect leads to a poor conceptual understanding. Science students at school X are taught introductory concepts in form three chemistry, such as the structure of the atom, bonding, chemical formulae for compounds, solutions and acids and bases. However, when these students start integrated science at the CSEC level (forms 4 and 5) they have difficulties in understanding the scientific concepts taught in reactivity of metals. This is manifested in the use of incorrect terms or misconceptions to answer and explain questions and analyse data in laboratory activities. In this action oriented study, misconceptions will be used to inform practice with the intention that students will develop sound conceptual understandings. The 5E Learning cycle approach will be used to execute lessons in this chemistry topic and students' conceptual understanding will be monitored throughout the study using concept maps.

1.2 Purpose of the study:

The purpose of this study monitor the development of conceptual understanding among form four science students in a secondary school using the 5E learning cycle (a constructivist approach). Students come to the classroom with misconceptions and usually have a poor understanding of the reactivity of metals. A constructivist approach in the classroom along with the use of concept maps will help to monitor conceptual development in this topic. It is hoped that students will gain a better understanding this topic which will allow them to be able to answer questions using the jargon associated with the science topic instead of using their misconceptions.

1.3 Significance of the Study:

This study will investigate the 5E Learning cycle in the development of students' conceptual understanding. The study will add to the growing body of research on conceptual understanding in science and will also help me as a teacher to improve my practice.

1.4 Overarching Research Question:

How does the use of the 5E Learning cycle influence the development of conceptual understanding of form four secondary school science students at school X?

1.4.1 Sub-questions:

1. What is the effect of the 5E Learning cycle on students' conceptual understanding of concepts related to the reactivity of metals? (Quantitative & Qualitative)
2. What are students' perceptions of the use of the 5E Learning cycle on their understanding of concepts? (Qualitative)
3. What are students' perceptions on the use of the 5E Learning cycle as a learning tool? (Qualitative)

1.5 Hypotheses:

Concept Scores:

H_o: there will be no difference in the concept scores ($\mu_o = \mu_1$). [The mean of the pre-concepts (μ_o) is equal to the mean of the post-concepts (μ_1)]

H_1: there will be a significant difference in the concept scores ($\mu_o \neq \mu_1$). [The mean of the pre-concepts (μ_o) is not equal to the mean of the post-concepts (μ_1)]

Concept Map Scores:

H_o: there will be no difference in the concept map scores ($\mu_o = \mu_1$). [The mean of the pre-concept map (μ_o) is equal to the mean of the post-concept map (μ_1)]

H_1: there will be a significant difference in the concept map scores ($\mu_o \neq \mu_1$). [The mean of the pre-concept map (μ_o) is not equal to the mean of the post-concept map (μ_1)]

1.6 Expected outcomes:

At the end of this study it is expected that after using 5E Learning cycle that form four integrated science students would have developed their conceptual understanding in a unit of work *'reactivity of metals'*.

Chapter 2

Literature Review

In this study the unit *'Reactivity of metals'* was taught using the 5E Learning cycle as the intervention to develop students' conceptual understanding. The form 4 Integrated Science students are at an adolescent age and according to Piaget (as cited in Caskey & Anfara, 2007) young adolescents, as learners, build upon their individual experiences and prior knowledge to make sense of the world around them. The 5E Learning cycle will allow "adolescents [to] benefit more from direct experiences than from abstract ideas and principles" (Stages of Growth Child Development, n.d).

2.0 *Conceptual Understanding*

Conceptual understanding has been the target of current research for more than forty decades. Madu & Amaechi (2012) state that teaching and learning of science should be geared towards making the learner acquire not just the facts but the understanding of the scientific concepts. Rowlands (as cited in Areepattamannil, Freeman, & Klinger, 2011, p.233) supports this statement by saying that science permeates every aspect of modern life and full enculturation into today's technological society necessitates the understanding of science. According to the National Science Education Standards (as cited in Aktan, 2013, p.35) :

> Understanding science requires that an individual integrates a complex structure of many types of knowledge, including the ideas of science, relationships between ideas, reasons for these relationships, ways to use the ideas to explain and predict other natural phenomena, and wants to apply them to many events.

Zirbel (n.d.) reinforced this statement stating that deep understanding means that the concepts are well represented and well connected. She goes on to say that deep understanding of a subject involves the ability to recall many connected concepts at once, where every single concept has a deep meaning in itself. Zirbel also states that not seeing connections between interelated concepts leaves the learner with a feeling of mindless thinking. When a learner "makes sense" of new material he is able to make the connections between different concepts

According to Girad and Wong (as cited in Saleh, 2011, p.249) conceptual understanding requires both knowledge of and the ability to use scientific concepts to develop mental models about the way the world operates in accordance with a current scientific theory…and that it develops a student's ability to apply facts and events learned from science instruction and from personal experiences with the natural environment, to use scientific concepts, principles, laws and theories that scientists use to explain and predict observations from the natural world.

According to Zirbel (2004) a concept can be defined as:

> Mental representations that, in their simplest form, can be expressed by a single word, such as apple or orange. Concepts may also represent a set of ideas that can be described in a few words. Through the use of language, individual concepts, can be connected to build more complex representational structures, such as "birds fly". At other times, two concepts can be combined to form a third representational structure. An example of the latter is density, which is the matter per volume. More complex concepts can describe a whole idea, such as the theory of natural selection.

According to Pines (as cited in Jones & Idol, 2013, p.140) he describes concepts as packages of meaning that capture regularities (similarities and differences), patterns, or relationships among objects, and other concepts. Pines goes on to emphasise that concepts represent different ways of organizing or "slicing up" the world.

Findings by Saleh (2011) reveal that most educators agree that science teaching and learning should move away from a system that promotes science primarily as recall of factual information and rote computation to one which emphasizes conceptual understanding and logical process skills. However, this goal has not been easily attainable. Literature reviews show that the problems of conceptual understanding are widespread among students. Studies have found that most students still have naïve ideas about concepts... high school and undergraduate students are generally found to have an understanding that is not scientifically accepted.

2.1 Misconceptions

From studies conducted, misconceptions go by many different names; such as alternative conceptions, preconceptions, alternative frameworks, naïve beliefs, naïve theories, naïve conceptions, children's scientific intiutions, conceptual frameworks, children's science, common sense concepts, alternative conceptual framework, intuitive conceptions, intuitive science, common alternative science conceptions, prescientific conceptions, alternate preceptions, students' descriptive and explanatory systems and spontaneous knowledge. Regardless of the term used, in science education, they "refer to ideas that students have about natural phenomena that are inconsistent with scientific conceptions and reflect the complex nature and multiple causes of children's erroneous conceptions as viewed by science educators" (Ozmen, 2004, p.148). In this study the term misconception will be used and it means "a concept that is not in agreement with our current understanding of natural science" (Zirbel, 2004, p.63). Uzuntiryaki & Geban (2005) support this, saying that misconceptions imply mistaken answers students give when confronted with a particular situation where their knowledge about how the world works differs from that of a scientist.

As stated earlier, the abstract nature of this chemistry topic and students' prior knowledge usually result in poor conceptual understanding. Metallic bonding will be included in this unit of work as well. Coll & Taylor (2002) mention that chemical bonding is a topic that students' commonly find problematic and for which they develop a wide range of alternative conceptions. De Posada; Taber (as cited in Coll & Taylor, 2002, p.176) state that many students … have a poor understanding of the bonding in metals, seeing it as weak or in some measure inferior to other forms of bonding.

Prior to the study, some misconceptions gathered from students were that a metal is a type of iron. Students believe that bonds melt and when heat is applied metals melt and this is evidence of reactivity and that extreme heat is required for metals to react for atoms to move faster and break their bonds. They associated rusting with 'old' objects and referred to it as rottening. Also, they went onto to say that harsh chemicals are responsible for rusting to occur and that rusting eats away the metal. It is clear that students have misconceptions in this topic in science, which need to be adressed in such a way that meaningful learning takes place.

These misconceptions "can be private versions of a student's understanding of particular concepts that have not been tested scientifically, or premature beliefs that do not stand the test of scientific analysis or that have not been exposed to it" (Zirbel, 2004, p.63). Even though these misconceptions maybe not be in line with the understanding of science, these concepts are usually students' current understanding which are available to them at that point in time. Even though these conceptions can be erroneous, it is important to note that they have been constructed based on students' "incomplete personal observation and inadequate analysis" (Zirbel, 2004, pg. 67).

Students would have gone through a process of reasoning to reach to this final outcome, thus to them their reasoning would be rational. This therefore, makes it hard for the student to change their misconceptions with newly attained knowledge. Nakleh (as cited in Uzuntiryaki & Geban, 2005, p.312) supports this, saying that after a student integrated misconceptions into his cognitive structure, these misconceptions interfere with subsequent learning. The student is then left to connect new information into a cognitive structure that already holds inappropriate knowledge. In fact "individuals whose ideas conflict with new information might disregard or discount the new information in favour of their existing beliefs, and they may even end up defending those beliefs" (Zirbel, 2004, p.62).

2.2 Conceptual Change and Conceptual Change Theory (CCT)

"When one forgets or deliberately avoids making connections between newly attained knowledge and well-established observations, the new scientific knowledge will not stay stable"(Barke, Hazari, & Yitburek, 2009). This will lead to the learner reverting to his original preconcepts.

Students "often come to school with already formed ideas on many topics, including how they view and interpret the world around themselves" (Zirbel, n.d.). Zirbel goes on to say that even when students might not yet have a pre-existing view, they will still try to make meaning of situation, often instantaneously, by making associations to somewhat related previous ideas and experiences. In this study the students' misconceptions were sought out in the forms on questions and from different studies which involved misconceptions in the reactivity of metals. This would have allowed the researcher to design lessons taking into consideration students' misconceptions.

This is supported in the literature by Barke et al. (2009) who states that:

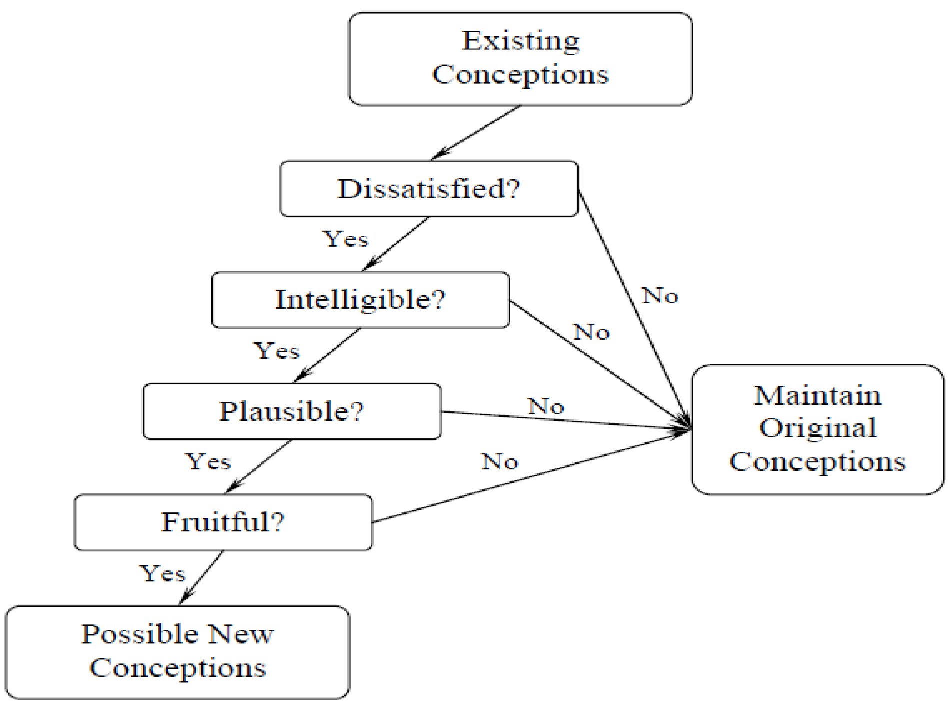
> teachers should not assume their students enter their classroom with no knowledge or ideas whatsoever. A lesson, which does not take into account that students have existing concepts, usually enables them to barely follow the lecture until the next quiz or exam. After that, newly acquired information will gradually be forgotten: students tend to return to their old and trusted concepts.

Only when students feel uncomfortable with their ideas, and realize that they are not making any progress with their own knowledge will they accept the teacher's information and thereby build up new cognitive structures. (Barke, Hazari, & Yitburek, 2009, p.28). "Errors are characteristics of initial phases of learning because students' existing knowledge is insufficient and supports only partial understanding. As their exisiting knowledge is recognized to be inadequate to explain phenomena and solve problems, students learn by transforming and improving that prior knowledge into more sophisticated forms." (Uzuntiryaki & Geban, 2005, p.213). Uzuntiryaki & Geban also state that meaningful learning requires well-organized relevant knowledge structure and high commitment to seek relationships between new and existing concepts. And that creating links is an important feature of Conceptual Change Theory (CCT), otherwise there is no difference between conceptual change and simple rote learning.

Uzuntiryaki (2003) also includes the fact that a constructivist approach seems to be effective in providing meaningful learning. In this approach, the learner relates the new information to his already existing knowledge. Students construct their knowledge by making links between their ideas and new concepts through experiences they acquire in school or daily life. These types of experiences can result from assimilation or accommodation. When assimilation occurs new knowledge is incorporated into existing cognitive structure or they can lead to disequilibrium in which experiences cannot be reconciled with the existing structure and accommodation, where cognitive structure is reorganized, occurs. Accommodation allows a return to cognitive equilibrium. Thus from this point of view, learning is a process of conceptual change.

According to Zirbel (2004) the conceptual change theory enables students to confront events which contradict their current conceptions. They have hypothesised four conditions necessary for conceptual change to occur; dissatisfaction, intelligibility, plausibility and fruitfulness (See Figure 1).

Figure 1. Conceptual Change Model



The conditions are as follows:

(1) Dissatisfaction. According to Zirbel (2004), dissatisfaction occurs when the learners must first realize that there are some inconsistencies and that their way of thinking does not solve the problem at hand.

(2) Intelligibility. Posner et al. (as cited in Zirbel, 2004, p.69) argued that for a learner to accommodate a new conception, he or she must find it intelligible. The concept should not only make sense, but the learners should also be able to regurgitate the argument and ideally be able to explain the concept to other classmates.

(3) Plausibility. "The new conception must be plausible for it to be accommodated. [Thus] the new concept must make "more" sense than the old concept. It must have the capacity to solve the problem better. The learners should be able to decide on their own how this new concept fits into their ways of thinking and recall situations where this concept could be applied" (Zirbel, 2004, p.69).

    The term accomodation refers to the "replacing or reorganizing the learner's central conceptions. It signifies a radical change involving abandoning an existing conception and accepting a new one" (Zirbel, 2004, p.68).

(4) Fruitfulness. "For the new conception to be accommodated, the learners must find it fruitful in the sense that this concept should have the potential to be extended to other incidences and open up new areas of inquiry. [Thus, the new concept] should do more than merely solve the problem at hand; it should also open new areas of inquiry" (Zirbel, 2004, p.69).

Tyson et al. (as cited in Uzuntiryaki & Geban, 2005, p.214) reinforces this saying that conceptual change is concerned with restructuring existing knowledge.

2.3 *The 5E Learning cycle*

According to Fosnot (as cited in Aktan, 2013, p.34) in the constructivist view of learning, students develop understanding when they integrate new knowledge to their existing understanding. This is supported by Gabel (2003) who states that during the learning process students' existing mental models must be modified for internal consistency and reconciled with scientists' understanding of the phenomena. "Students learn meaningfully when they activate their existing knowledge, relate it to educational experiences and construct new knowledge in the form of conceptual models" (Glynn & Duit, 1995, p.5).

Artun & Costu (2012) have found that science education researches have established that students' alternative conceptions in science are very tenacious and that traditional instruction is not very effective in promoting conceptual understanding. "Unfortunately, the traditional approaches often used by teachers do not offer the opportunity for student participation in the learning of science" (Madu & Amaechi, 2012, p.173). In addtion, this study takes place in an urban school and research suggests that "students in an urban environment are more successful when they take a more active part in their education and the classroom environment becomes more student-centred" (Hokkanen, 2011, p.4).

Studies have revealed that teaching and learning must be an interactive process that engages the learners in constructing knowledge and that the teaching approach is important in science for promoting meaningful learning and elminating misconceptions. One such approach is the use of a conceptual change approach. Studies have revealed that the Engagement, Exploration, Explanation, Extension and Evaluation (5E) Learning model is successful in facilitating conceptual understanding. The 5E Learning model is an example of a conceptual change model. This means that the model will create four conditions for conceptual change to occur; dissatisfaction, intelligibility, pluasibility and fruitfulness.

Figure 2. A diagram illustrating the 5E Learning cycle

The 5E Learning cycle (See Figure 2) is an instructional model based on the constructivist approach. "[It] is a hands-on, minds-on teaching strategy based on Piaget's developmental model of intelligence that makes students aware of their own reasoning by helping students reflect on their activities" (Balci, Cakiroglud, & Tekkaya, 2006). The unit of work in this study will involve a lot of experimental activities, thus the 5E Learning cycle will be ideal to promote conceptual change and remedy existing misconceptions. According to Balci et al. (2006), the 5E Learning cycle :

> Begins with the active *engagement* of students in investigating the natural phenomena. During *exploration*, the teacher acts as a faciliator, providing materials and directions, guiding the physical process of the experiment. After the exploration, the teacher promotes a discussion period in which students share their observations with classmates (*explanation*). This is the time in which the teacher connects students experiences to target science concept including the identification of scientific vocabulary. Once the concept has been labelled,

> students engage in additional activities (*extension*) in which they apply their recently formed understandings to new situations.

It is important to note that "the Engagement phase of the cycle is designed to captivate students' attention and uncover their prior knowledge about the concept(s), while the Evaluation phase (which comes after the extension) is an opportunity for the teacher to assess students' progress, as well as for students to reflect on their new understandings" (Hanuscin & Lee, 2007, p.7).

According to Tasdelen & Koseoglu (2008) the constructivist learner [has] a more important role in the learning processes. Therefore, learning shifts from being teacher-centred to more student-centered. "Primary, middle and secondary school science teachers are expected to create learning environments that facilitate students' construction of science understandings, skills and attitudes" (Rahayu, Chandrasegaran, Treaugust, Kita, & Ibnu, 2011, p.1439). According to Carey (as cited in Rahayu et al., 2011) meaningful learning does not involves mere passive absorption of information but rather involves the active creation and modification of knowledge structures. Also, "rote learning with little or no transfer of knowledge [does not] allow students to assimilate what they are taught because they are not actively involved in the learning process" (Madu & Amaechi, 2012, p.173).

"For scientists, meaningful conceptual understanding in science goes far beyond knowing facts and label. Rather, conceptual knowledge becomes meaningful only when it can be used to explain or explore new situations" (Jones & Idol, 2013, p.141). Thus a constructivist approach can help to improve conceptual understanding.

The 5E Learning cycle is not only effective in enhancing students' understanding; it also promotes student autonomy. "[The] students learn through their own involvement and action…"

(Akar, 2005, p.27). Akar says this is because the learning cycle encourages students to develop their own frames of thought. Thus "students should be given the freedom to understand and construct meaning at their own pace through challenging personal experiences and through peer interactions…in the classroom" (Kilavuz, 2005).

2.4 Concept Mapping

In this study, concept mapping will be used to monitor students' conceptual change and thus be able to track their understanding. A study conducted by Novak and Musonda in 1991, sought to follow and understand changes in children's knowledge of science. Researchers were met with difficulties in identifying "specific changes in children's understanding of science concepts by examination of interview transcripts" (Novak & Canas, 2006, p.3). Thus out of necessity to find a better way to represent children's conceptual understanding emerged the use of concept mapping.

Concept mapping is an authentic assessment tool to assess and promote students' conceptual understanding and conceptual change. "In order to promote conceptual change, concept mapping, which indicates relationships among concepts, can be used" (Uzuntiryaki & Geban, 2005, p.318). "Studies suggest that concept mapping offers a valid and potentially useful technique for exploring conceptual change in science" (Kaya, 2008, p.93). Kaya (2008) also used concept mapping as the only assessment tool to assess and promote the understandings regarding chemical concepts in a university general chemistry laboratory.

According to Novak (as cited in Uzuntiryaki & Geban, 2005, p.318) concept maps are diagrams constructed to represent an individual's understanding of a particular topic or area. Concept maps will be used at the start of the lesson to gather students' misconceptions.

According to Jones et al. (as cited in Uzuntiryaki & Geban, 2005, p.318) research has shown that concept maps are useful tools that reveal students' existing ideas. Uzuntiryaki & Geban (2005) also state that teachers can use concept maps for obtaining information on what students know, how their conceptions are related to each other…teachers [also] have the opportunity to identify some misconceptions that prevent construction of meaningful knowledge and check the effects of teaching on students' cognitive structures.

At the end of each lesson taught in this study students will be given the opportunity to construct another concept map, this will "give students an opportunity to: (1) think about the connections between the science terms being learned, (2) organize their thoughts and visualize the relationships between key concepts in a systematic way, and (3) reflect on their understanding (Vanides, Yin, Tomita, & Ruiz-Primo, 2005, p.28).

"Concept maps have been particularly helpful in representing qualitative aspects of students' learning. They may also be used by students as a study tool, or by teachers to evaluate learning…" (Edmondson, 2005, p.20). Edmondson (2005) goes onto say that concept maps may be used effectively to depict an array of qualitative aspects of student understanding. She goes on to state that as assessment tools, concept maps may be used summatively, as tests, but they may also be used to document changes in knowledge and understanding over time.

"Concept mapping requires students to identify important concepts and show interrelationships between them. Therefore, it allows students to give a personal meaning to subject content thinking in multiple directions. It means that students realise the links among concepts" (Uzuntiryaki & Geban, 2005, p.321). This is supported by Ruiz-Primo (2000) who states that a potential instrument to capture important aspects of this interrelatedness between concepts is concept maps.

According to Ruiz-Primo (2000) a concept map is a graph consisting of nodes and labelled lines. The essential parts of a concept map are as follows; nodes correspond to important terms or concepts. Lines between two nodes represent a relationship between the concepts and a labelled line indicates how the two concepts are related. A combination of two nodes and a labelled line is known as a proposition. Dochy (as cited in Ruiz-Primo, 2000) states that a proposition is the basic unit of meaning in a concept map and the smallest unit that can be used to judge the validity of the relationship drawn between two concepts. According to Markham & Mintzes (as cited in Daniel Tan, 2000, p.47) the number of valid concepts and propositions will indicate the amount of scientifically acceptable knowledge that a student has…while the number of cross-links suggest conceptual integration or cohesion.

Concept mapping can be high-directed or low-directed. In high-directed mapping techniques "students do not select the concepts to be used in the map, or which concepts to connect, or the words for explaining the relationship between the concepts, or the structure of the map" (Ruiz-Primo, 2000, p.34). In this study "students are free to decide which and how many concepts to include in their maps, which concepts are related, and which words to use to explain the relation between concepts" (Ruiz-Primo, 2000, p.35). This is characteristic of a low-directed mapping technique. Ruiz-Primo and other researchers state that a low-directed technique in concept map construction will directly reflect the students' knowledge sturucture. They go on to suggest that as the students' subject matter knowledge increases, the structure of students' maps should increasingly reflect the structure of the domain as held by experts. Therefore, using a high-directed technique, “it is difficult to know whether or not students’ knowledge structures are becoming increasingly similar to experts’.

Chapter 3

Methodology

3.0 Research Design:

This is an action research study which can be defined as "a disciplined process of inquiry by and for those taking the action" (Sagor, 2000). The researcher will be taking action in this study in the role of the teacher. The teacher will be using the 5E Learning cycle and concept maps to develop and monitor the participants' conceptual understanding in the unit of work 'reactivity of metals'. Thus, it is meant to "bring about change in specific contexts" according to Parkin (as cited in Koshy, Koshy, & Waterman, 2011, p.1). According to Meyer (as cited in Koshy et al., 2011, p.2) action research's strength lies in its focus on generating solutions to practical problems and its ability to empower practitioners, by getting them to engage with research and the subsequent development or implementation activities. The researcher will be engaged in this study through the implementation of the 5E Learning cycle which will be used to remedy the participants' misconceptions. It will prompt the researcher to critically examine her practice and to consider ways for improvement.

According to Kemmis and McTaggart (as cited in Koshy, Koshy, & Waterman, 2011, p. 5) action research involves a spiral of self-reflective cycles of (See Figure 3):

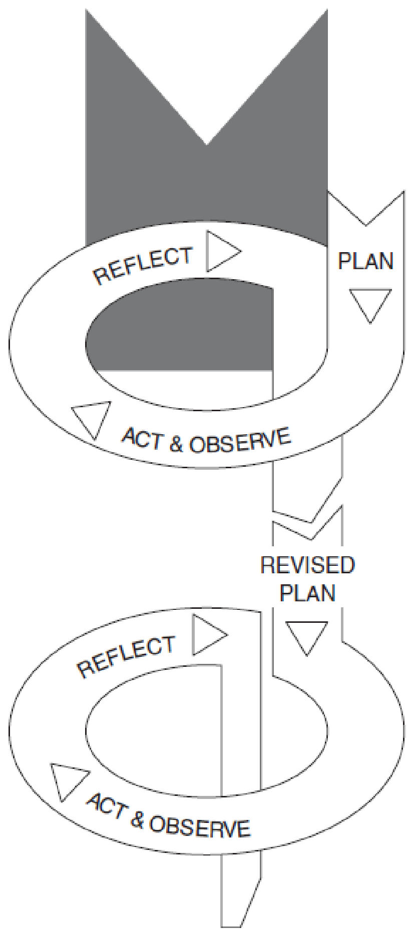
1. Planning a change.
2. Acting and observing the process and consequences of the change.
3. Reflecting on these processes and consequences and then replanning.
4. Acting and observing.

5. Reflecting.

6. And so on…

Thus, even after this study has been conducted, the teacher's practice doesn't come to an end but will continue, to improve the practice further using this reflective cycle.

Figure 3. Kemmis and McTaggart's action research spiral



In this action research study, a pragmatic approach will be taken. According to (Johnson & Christensen (2011) in pragmatism, what is ultimately important is what works in practice … and it focuses on the ends that we desire. "Pragmatism is not committed to any one system of philosophy and reality. This applies to mixed methods research in that inquirers draw liberally from quantitative and qualitative assumptions when they engage in their research" (Creswell, 2009, p.10). In this approach, "by focussing on solving practical problems, the debate about the existence of objective "truth" or the value of subjective perceptions, can be usefully sidestepped" (Weeldon, 2010).

In this study students' conceptual understanding was monitored using concept mapping. Concepts maps "may be especially valuable from a pragmatist's point of view because visualizing and imagining connections and relationships can be creative, distinctive and thus productive in ways other kinds of data collection may not be" (Chapter 5 Mapping Mixed-Methods Research: theories, models and measures, n.d). The chapter goes on to state that the mapping process is best suited to mixed-methods researchers because as a data-collection technique, it can offer both numeric and narrative data, provide a means to showcase analysis procedures, or even be a means to present research findings. This flexibility is in line with mixed methods as a pragmatic approach.

A mixed methods approach "is an approach to inquiry involving collecting both quantitative and qualitative data" (Creswell, 2013, p.4). Creswell goes onto say that the combined approaches provide a complete understanding of a research problem being studied. According to Plano Clark, Creswell, O'Neil Green, & Shope (2010) stronger more corroborated conclusions can be obtained when the results are derived from two different types of data instead of only a single type. A combination of quantitative and qualitative approaches in this action research study were used for data collection to determine and monitor the development of conceptual understanding in secondary science students using the 5E Learning cycle-a constructivist approach- on the unit of work *'Reactivity of metals'*.

Pre- and post- concept maps were used to monitor the conceptual understanding from lesson to lesson and a summative concept achievement test (SCAT) were used to determine whether conceptual change did occur. Also, journals were used to investigate students' perceptions on the use of the 5E Learning cycle in their learning.

3.1 Overarching Research Question:

How does the use of the 5E learning cycle influence the development of conceptual understanding of form four secondary school science students at school X?

3.1.1 Sub-questions:

1. What is the effect of the 5E learning cycle on students' conceptual understanding of concepts related to the reactivity of metals? (Quantitative & Qualitative)
2. What are students' perceptions of the use of the 5E learning cycle on their understanding of concepts? (Qualitative)
3. What are students' perceptions on the use of the 5E learning cycle as a learning tool? (Qualitative)

3.2 Hypotheses:

Concept Scores:

H_o: there will be no difference in the concept scores ($\mu_o = \mu_1$). [The mean of the pre-concepts (μ_o) is equal to the mean of the post-concepts (μ_1)]

H_1: there will be a significant difference in the concept scores ($\mu_o \neq \mu_1$). [The mean of the pre-concepts (μ_o) is not equal to the mean of the post-concepts (μ_1)]

Concept Map Scores:

H_o: there will be no difference in the concept map scores ($\mu_o = \mu_1$). [The mean of the pre-concept map (μ_o) is equal to the mean of the post-concept map (μ_1)]

H_1: there will be a significant difference in the concept map scores ($\mu_o \neq \mu_1$). [The mean of the pre-concept map (μ_o) is not equal to the mean of the post-concept map (μ_1)]

3.3 Procedure:

3.3.1 Sample group:

Data for this study were drawn from School X, a denominational school in the school district of Port-of-Spain and Environs from a class containing 16 female form four students, aged 15-17 years pursuing integrated science at the CSEC general proficiency level. This is a purposive sampling where the sample was deliberately selected in order to achieve a certain goal. The form four students were chosen as they have a poor understanding of concepts and scientific terms and display misconceptions in the chemistry topic reactivity of metals.

3.3.2 Process of data analysis:

The study was conducted over a four-week period. The classroom instruction of the sample group varied from 1-hr to 2-hrs per week. Prior to the study, the teacher gathered misconceptions or alternate conceptions from the literature and from students. Students participating in this study answered a series of questions related to the topic prior to the intervention (See Appendix A). The unit of work ‘reactivity of metals’ contained five lessons (See Appendix B) that were designed around gathered misconceptions. This was to ensure that students moved towards views more in accord with scientific views for the concepts. This is supported by Barke, Hazari, & Yitburek (2009) who state that lessons should not merely proceed from ignorance to knowledge but should rather have one set of knowledge replace another. Chemical education should be a bridge between students' preconcepts and today's scientific concepts. Barke et al. (2009) also state that teachers cannot automatically assume that in a particular lesson any preconceptions regarding this lesson will appear. It is necessary to diagnose such concepts and, in the case of misconceptions, to plan a lesson which integrates new information with these concepts.

Barke et al. (2009) go on to say that a lesson which does not take into account that students have existing concepts, usually enables them to barely follow the lecture until the next quiz or exam. After that, newly acquired information will gradually be forgotten: students tend to return to their old and trusted concepts.

The students were taught using the 5E Learning cycle, were engaged in hands-on activities and class discussions. Each lesson consisted of five parts- engage, explore, explain, elaborate and evaluate. The teacher emphasized common misconceptions by asking questions in the engagement stage. Students' responses were noted on the board. Here, students were given the opportunity to construct a pre-concept map. Another concept map (post-concept map) was constructed in the evaluation stage after the lesson's content was covered. Here students used concept maps to organize their knowledge to show links between concepts learnt. The purpose of the pre- and post- concept maps was to monitor students' conceptual understanding and for students to become aware of their conceptual changes. It is important to note that students would have had previous exposure to concept mapping prior to the study.

Table 1

Outline of lessons

Lesson #	Title of lesson	Alternate conception(s) to be addressed
1	Physical properties and Bonding in Metals	Type of bonding, physical properties metals possess and type of particles present in metals
2	Displacement Reactions (I)	Type of particles present in salt solutions, type of reaction
3	Displacement Reactions (II)-reaction between metals and acids	Type of reaction, gas production
4	Tarnishing-reaction between metals and oxygen	Type of reaction, mass of product formed, metals involved in tarnishing
5	Rusting	Type of reaction, mass of product and metals that undergo rusting

3.4 Data collection instruments:

Conceptual Understanding:

Two sources of data, Summative concept achievement test (SCAT) and concept mapping were used to monitor the development of students' understanding in the reactivity of metals in this study.

3.4.1 Concept mapping:

Concept mapping was also used in each lesson to monitor students' conceptual understanding and explore their conceptual change. The concept mapping exercise was administered twice, i.e. immediately before (pre-) in the engagement stage and after (post-) in the evaluation stage of the 5E Learning cycle. The concept maps were constructed by the students themselves using pencil and paper. The concept mapping technique was low-directed, that is, students constructed the maps themselves from scratch using concepts gathered during the lesson. Students were allowed to organize the terms in relation to one another in any way they wanted. “A low-directed technique provided students with more opportunities to use their conceptual understanding than the high-directed techniques” (Ruiz-Primo, 2000, p.46). The concept map evaluation involved an examination of its components using the component strategy.

3.4.2 Summative concept achievement test (SCAT) :

A summative concept achievement test (SCAT) (See Appendix C) was purposely designed to assess the development of students’ conceptual understanding and to determine any conceptual change. The test is a two-tier multiple choice diagnostic instrument which consisted of 15 items. The content of the test was related to concepts covered in the unit of work ‘reactivity of metals’ and alternate misconceptions gathered. In the SCAT, the first-tier choice examined factual knowledge while the second-tier choices examined the reasons behind the first-tier; a reasoning response. For items 1 to 13, the reasoning response had to be chosen from four responses. One of the responses was the expected reason, the remaining three were distractors. The distractors of the test items reflected students’ misconceptions detected from the relevant literature and concept maps. The reasoning responses, for items 14 to 15 were free response, thus students had to give their own reasoning response. The questions sought to probe more deeply into students’ understanding. The SCAT would measure the students’ understanding of concepts of the entire class. It would be easy to administer and score as well.

3.4.3 Journals:

Students participating in the study were asked to write a journal entries at the end of lessons one, three and six. The journals were used to collect data to answer research questions two and three. The students were guided by the following questions:

1. What aspects of the lesson(s) that you experienced, do you consider to be helpful/beneficial to your learning? Give reasons for your answer.

2. What aspects of the lesson(s) that you experienced were not helpful/enjoyable to your learning? Give reasons for your answer

3. Do you believe that your understanding of the topic thus far has improved through the way the lesson(s) was taught? Give reasons for your answers.

4. What aspects of the lesson(s) helped you with the understanding of the content taught?

5. What parts of the lessons ***helped*** in your ***understanding***? Was it (i) the Introduction, (ii) the Class activity (iii) the Class discussions or (iv) the concept maps? Say why? Note: You are <u>not</u> confined to commenting on only one part of the lesson.

6. What parts of the lessons did ***not help*** in your ***understanding***? Was it (i) the Introduction, (ii) the Class activity (iii) the Class discussions or (iv) the concept maps? Say why? Note: You are <u>not</u> confined to commenting on only one part of the lesson.

7. What part of the lessons ***helped*** you in your ***learning***? Was it (i) the Introduction, (ii) the Class activity or (iii) the Class discussions? Say why? Note: You are <u>not</u> confined to commenting on only one part of the lesson.

8. What part of the lessons was ***not beneficial*** to your ***learning***? Was it (i) the Introduction, (ii) the Class activity or (iii) the Class discussions? Say why? Note: You are not confined to commenting on only one part of the lesson.

Questions 1 to 4 were used in the first and third lessons. These questions were then redesigned to questions 5 to 8 for the sixth lesson. The journal questions to elicit pertinent information related to the research questions. Students were assigned a letter to replace their actual names. This was to protect the identity of the students and to maintain the students' confidentiality.

3.5 Data analysis:

3.5.1Concept Mapping:

In this study, pre- and post-concept maps where compared to monitor the students' conceptual understanding and explore the students' conceptual change. The concept maps were analysed quantitatively and qualitatively. For the quantitative analysis, the pre- and post-concept maps were analysed using combined strategies adapted from a study done by Kaya (2007). A component strategy was adopted, identifying four criteria to be considered when assessing the concept maps. They are the validity of the concepts, adequacy of propositions, significance of the cross-links and relevancy of examples. Also, a symbol system with a scoring scheme was used along with the component strategy.

Each valid concept was awarded one point with the symbol °, while each correct proposition was awarded two points with the symbol * . "A proposition is a short meaningful phrase that connects two or more concepts with a line, and labelling this line with a linking word indicates a relationship among the concepts" (Kaya, 2008, p.99). Unclear propositions were represented with the symbol ?. “An unclear proposition consisted of unlabelled relationship among concepts, incorrect isolated concepts and linking words, or insufficient explanation of the relationship between concepts” (Kaya, 2008, p.99). Each valid and significant cross-link was awarded 5 points with the symbol X and each example of a concept was given one point with the symbol α.

The total scores (See Appendix F) were calculated using the following equation (valid concepts x 1 point) + (valid proposition x 2 points) + (valid and significant cross-links x 5 points) + (valid examples x 1 point).

The scores were also analysed using descriptive statistics including, mean, median, range and standard deviation and maximum and minimum score. The mean scores of concepts in the pre- and post- concept maps and the total scores of the pre-and post- concept maps were compiled. A paired *t* test for dependent means was carried out at the significance level, $\alpha = 0.05$ for each lesson to determine the significant changes in the pre-and post -concept maps,

The following null and alternative hypotheses were adopted in the analysis of the concept maps for each lesson:

Hypotheses:

Concept Scores:

H_o: there will be no difference in the concept scores ($\mu_o = \mu_1$). [The mean of the pre-concepts (μ_o) is equal to the mean of the post-concepts (μ_1)]

H_1: there will be a significant difference in the concept scores ($\mu_o \neq \mu_1$). [The mean of the pre-concepts (μ_o) is not equal to the mean of the post-concepts (μ_1)]

Concept Map Scores:

H_o: there will be no difference in the concept map scores ($\mu_o = \mu_1$). [The mean of the pre-concept map (μ_o) is equal to the mean of the post-concept map (μ_1)]

This was used to determine if to reject or accept the null hypothesis.

A qualitative analysis of the concept maps was also done based students' responses contained within the concept maps as well. Students' responses were also used to support the statistical data. "Qualitative assessment methods produce descriptive assessments of concept maps. Rather than aggregating concept map features into a single number, they make a synthesis of the various features and provide a descrptive diagnosis of the underlying extent of understanding" (Keppens, 2007). Through a comparison of the pre- and post-concept maps, a number of interseting narrative observations can be made. The qualitatve data was then cross analysed as well with the results from the SCAT.

3.5.2 Summative concept achievement test (SCAT):

At the end of the intervention, students were administered a summative concept achievement test (SCAT) consisting of 15 multiple choice questions. The mean, mode, median standard deviation, percentile, minimum and maximum score were calculated on the participants' overall scores. In addition, each multiple choice response required students to give an explanation for the answer they chose. Responses to the items were scored using the following assessment criteria in Table 2.

Table 2

Assessment criteria for summative concept achievement test (SCAT)

Categories		Marks
Content	Explanation	
Correct response	Correct reason	3
Incorrect response	Correct reason	2
Correct response	No reason	2
Correct response	Incorrect reason	1
Incorrect response	No reason	0
Incorrect response	Incorrect reason	0
No response	No reason	0

Overall, the questions would give information on students' conceptual understanding and determine if any conceptual change took place. The data were analysed using descriptive statistics including mean, mode, median, range, percentile, standard deviation and the maximum and minimum score. See Appendix D for a copy of the school's grading system. Further analysis was carried out on the SCAT. Subscales were made for the items that tested the same concept or aspect of the same concept. The subscales that emerged from the lessons taught in the unit of work were:

1. Structure & Properties of metals items (2, 3, 4, &10)
2. Displacement items (5, 6, 7, 12, 13, 14 & 15)
3. Tarnishing items (1)
4. Rusting items (8, 9 & 11)

3.5.3 Journals:

Journals were used to determine students' perceptions on the 5E Learning cycle as a learning tool and how its use helped in students' conceptual understanding. The journals were read and re-read and scrutinized line by line. The data from the journals were then colour -coded according to similarities. The data were then reduced into meaningful segments and the identified segments were assigned names or coded.

Once the codes were developed, categories were generated through a process of comparison, which would highlight similarities as well as differences. In order to do this, the categories, codes were compared. Codes that were related or similar were grouped to form categories. Patterns, contradictions and any inconsistencies were also examined. The categories were also refined as the data analysis process progressed.

3.6 Ethical considerations:

Prior to the start of the study, written consent was sought from parents of the students who were to participate in the study (See Appendix E). The consent forms identified that the identity of the participants would remain confidential and anonymous. Also, the content to be taught would in no way obstruct the students from completing the integrated science syllabus. Participants were given the option to withdraw from the study.

3.7 Experience in conducting the study over a timeline:

The study began due to the reoccurring problem in this topic at the form four level in integrated science. Over the four week period, journal questions were revised, as the lessons progressed and data were collected. Time management of the lessons were challenging using this new teaching strategy, even though the different parts of the lessons were timed.

3.8 Delimitations:

The study was restricted to a form four integrated science class at the Secondary level in School X in the Port-of-Spain and Environs Educational District.

3.9 Limitations:

The time period the study was conducted may not have been sufficient time for students to develop conceptual understanding in this topic and student attendance would have been a contributing factor in students' development of conceptual understanding. In addition, all cost associated with this study will rest solely on that of the researcher.

Chapter 4

Data Analysis and Presentation of Findings

4.1 Overarching Research Question:

How does the use of the 5E learning cycle influence the development of conceptual understanding of form four secondary school science students at school X?

4.1.1 Sub-research questions:

1. What is the effect of the 5E learning cycle on students' conceptual understanding of concepts related to the reactivity of metals? (Quantitative & Qualitative)
2. What are students' perceptions of the use of the 5E learning cycle on their understanding of concepts? (Qualitative)
3. What are students' perceptions on the use of the 5E learning cycle as a learning tool? (Qualitative)

4.2 Hypotheses:

Concept Scores:

H_o: there will be no difference in the concept scores ($\mu_o = \mu_1$). [The mean of the pre-concepts (μ_o) is equal to the mean of the post-concepts (μ_1)]

H_1: there will be a significant difference in the concept scores ($\mu_o \neq \mu_1$). [The mean of the pre-concepts (μ_o) is not equal to the mean of the post-concepts (μ_1)]

Concept Map Scores:

H_o: there will be no difference in the concept map scores ($\mu_o = \mu_1$). [The mean of the pre-concept map (μ_o) is equal to the mean of the post-concept map (μ_1)]

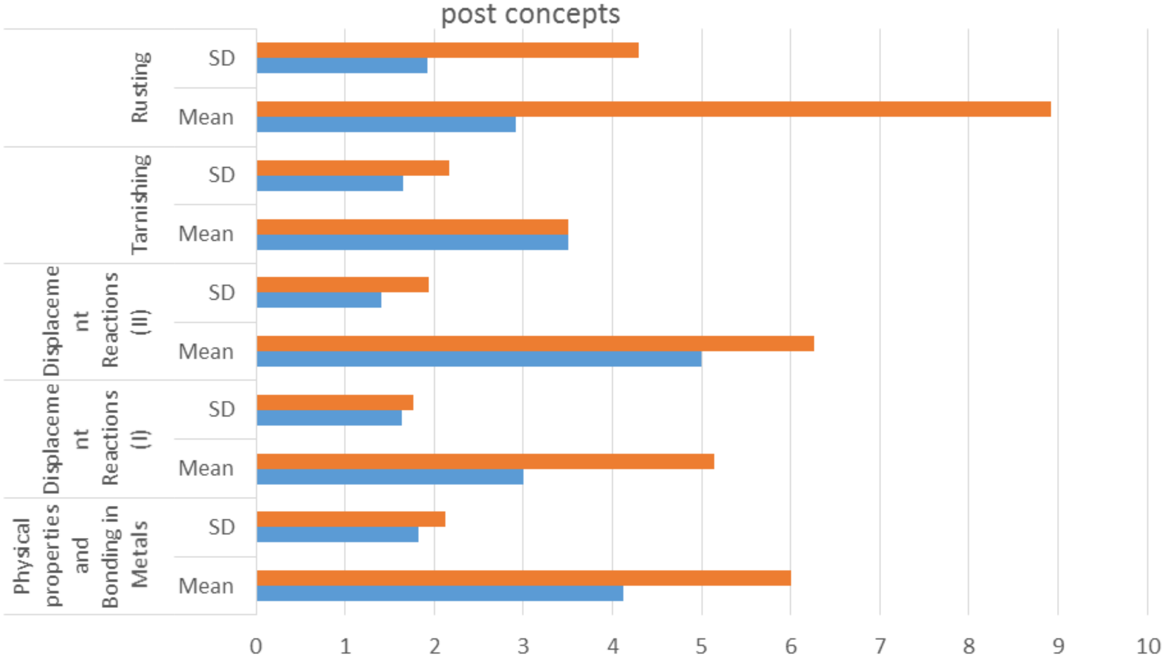
H_1: there will be a significant difference in the concept map scores ($\mu_o \neq \mu_1$). [The mean of the pre-concept map (μ_o) is not equal to the mean of the post-concept map (μ_1)]

The following sections present the key findings of this study.

<u>4.3 Effect of the 5E Learning cycle on concepts and concept maps:</u>

From Figures 4 and 5, the bar charts show statistical data for the pre- and post- concept scores and the pre- and post- concept map scores for the five lessons taught using the 5E learning cycle.

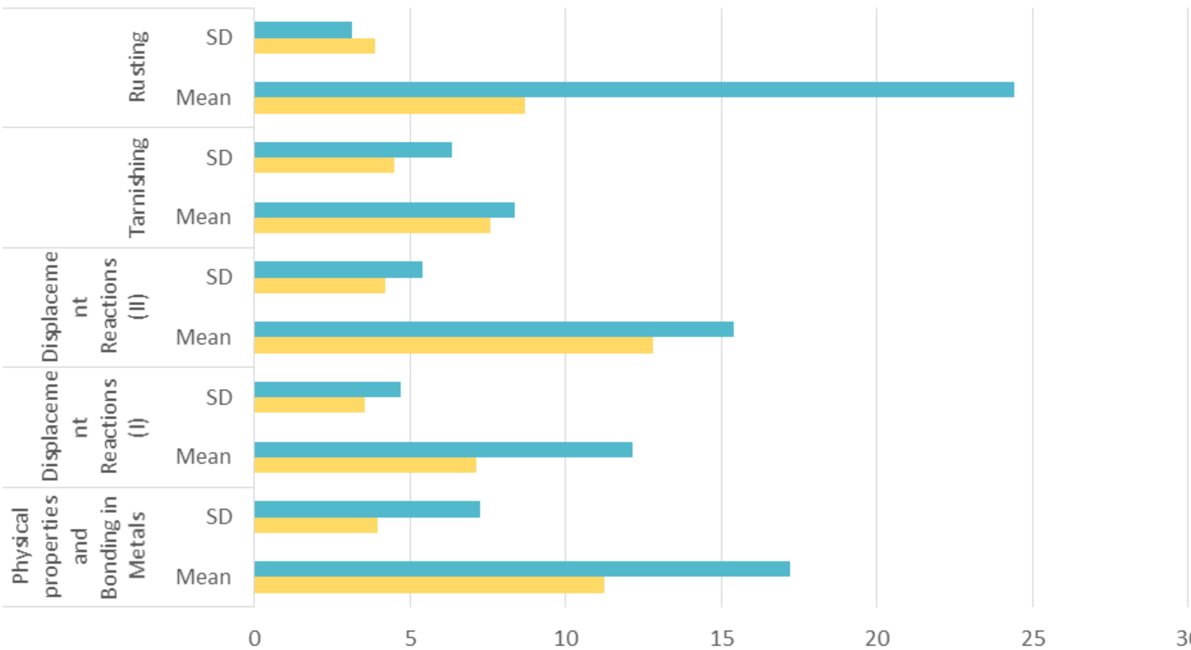
Figure 4. Bar chart illustrating the mean and standard deviation of pre and post concepts



	Physical properties and Bonding in Metals		Displacement Reactions (I)		Displacement Reactions (II)		Tarnishing		Rusting	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Post Concepts	6	2.13	5.14	1.77	6.27	1.94	3.5	2.17	8.92	4.3
Pre Concepts	4.13	1.82	3	1.63	5	1.41	3.5	1.65	2.92	1.93

In Figure 4, both mean and standard deviation show an increase in the post concepts for all the lessons taught. The post concept standard deviation of 4.3 for the lesson done on rusting had a mean of 8.92, while the pre concept (SD= 1.93, M= 2.92). This indicates a wider spread of the concept scores in the post scores about the mean. It is important to note that the mean for the lesson done on tarnishing was 3.5 for both pre and post concepts.

Figure 5. Bar chart illustrating the mean and standard deviation of pre and post concept maps



	Physical properties and Bonding in Metals		Displacement Reactions (I)		Displacement Reactions (II)		Tarnishing		Rusting	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Post Concept Maps	17.19	7.23	12.14	4.71	15.4	5.41	8.36	6.34	24.42	3.14
Pre Concept Map	11.25	3.97	7.14	3.53	12.8	4.21	7.57	4.5	8.67	3.87

In Figure 5, the mean and standard deviation for four lessons showed a significant increase. The standard deviations for these lessons showed a wider spread about the mean. However, for the rusting lesson , the post concept maps had a standard deviation of 3.14, with a mean of 24.42, while the pre-concepts (SD= 3.87, M= 3.87). This indicates a smaller spread about the mean in the post concepts.

Table 3

Summary of descriptive data of the total pre and post concept scores

	Physical properties and Bonding in Metals		Displacement Reactions (I)		Displacement Reactions II		Tarnishing		Rusting	
	Pre	post	Pre	post	pre	post	pre	post	pre	post
Mean	4.13	6.00	3.00	5.14	5.00	6.27	3.50	3.50	2.92	8.92
Median	4	6	3	5	5	7	3	3.50	2.5	9.5
Minimum score	0	3	1	3	3	3	1	1	1	4
Maximum score	7	9	6	8	7	11	7	7	6	15
Skewness	-.589	-.095	.964	.708	.000	.576	.358	.131	.597	.209

Table 4

Summary of descriptive data of the total pre and post concept map scores

	Physical properties and Bonding in Metals		Displacement Reactions (I)		Displacement Reactions II		Tarnishing		Rusting	
	Pre	post	Pre	Post	pre	post	pre	post	pre	post
Mean	11.25	17.19	7.14	12.14	12.80	15.40	7.57	8.36	8.67	24.42
Median	11.5	16.5	7	12	12	15	6.5	7	10	21
Minimum score	2	7	1	3	5	3	3	1	3	12
Maximum score	18	30	11	17	21	26	19	21	14	43
Skewness	-.437	.196	-.737	-1.20	.432	-.247	1.21	.608	-.23	.590

In Table 3 and 4, the statistical data shows both pre and post scores for the concepts and concept map scores for the 5 lessons taught (See Appendix G for calculations).

4.3.1 Physical properties and Metallic Bonding in Metals Lesson: In Table 3, the pre score, the median (4) was slightly lower than the mean (4.13), which indicates the data was positively skewed with a value of -.589. Both the minimum and maximim scores were 0 and 7 respectively. Whereas, the mean and median had the same value of 6 for the post scores.The minimum and maximum scores were 3 and 9 respectively. Even though the mean and median had the same value, the skewness value was still -.095 indicating the data was positively skewed.

In Table 4, The mean and median in the pre score was 11.25 and 11.5 respectively. The skewness had a value of -.437, indicating the data was postively skewed. The minimum and maximum scores were 2 and 18 respectively. However, in the post scores, the mean was 17.19 and the median was 16.5. the skewness was negative with a value of .196, inidcating most of the values concentrated to the right. The minimum and maximum scores were 7 and 30 respectively. The skewness values for both concept and concept map scores did improve, indicating an improvement in the scores.

A paired sample *t*- test shows for dependent means was carried out on this lesson, revealed a significant difference between the mean score for the pre concepts (M= 4.13, SD= 1.82, N= 16) and the mean score for the post concepts (M= 6.00, SD= 2.13, N= 16), with t (15) = -4.038, p=0.001, α= 0.05. Therefore, since 0.001 < 0.05, the null hypothesis is rejected. There was also a significant difference between the mean score for the pre-concept maps (M=11.25, SD=3.98, N= 16) and the mean score for the post-concept maps (M=17.19, SD=7.232, N= 16), with t (15) =-3.296, p=0.005, α= 0.05. Therefore, since 0.005 < 0.05, the null hypothesis is rejected (See Appendix G for calculations).

4.3.2 Displacement II Lesson: In Table 3, the pre score for the concepts, the mean and median both had a value of 5 with a skewness of 0, indicating that there was a normal distribution of scores. The maximum and scores were 7 and 3 respectively. For the post score however, the mean was 6.27 with the median at 7. The skewness value was .576, indicating the values were negatively skewed. The minimum and maximum scores were 3 and 11 respectively.

In Table 4, the pre score for the concept maps had a mean of 12.80 and a median of 12. The skewness value was at .432, indicating a negative skewness even though the mean was greater than the median. The minimum and maximum scores were 5 and 21 respectively. The post scores had a higher mean (15.40) than the median (15). The skewness was -.247, indicating the data was postively shewed. The maximum and minimum scores were 26 and 3 respectively.

For the paired sample *t*-test, both the concepts and concept maps showed a significant difference. Tests reveal a significant difference between the pre and post concepts and the pre and post concept maps. For the concepts, the mean pre score was 5.00 (SD=1.41, N=15) and the mean post score was 6.27 (SD= 1.94, N= 15), with t (14) = -2.74, p= 0.016, α= 0.05. Since, 0.016 < 0.05, the null hypothesis is rejected. In the concept maps, the mean pre score was 12.80 (SD=4.21, N=15) and the mean post score was 15.40 (SD= 5.41, N=15), with t (14) = -2.79, p= 0.014, α= 0.05. Since, 0.014 < 0.05, the null hypothesis is rejected.

4.3.3 Rusting Lesson: In Table 3, the pre score had a mean value of 2.92 and a median of 2.5, with a skewness value of .597, indicating it was postively skewed. Minimum and maximum values were 1 and 6 respectively. However, the post score, had a mean of 8.92 and a median of 9.5. The values were also negatively skewed with a value of .209. The maximum and mimimum values were 15 and 4, in that order.

While in Table 4, the pre scores the mean (8.67) was lower than the median (10). Despite this the skewness value was -0.23. The minimum and maximum scores were 3and 14 respectively. In the post scores, the mean (24.42) was higher than the median (21). The skewness was 0.59, indicating it was negative.The minimum and maximum values were 12 and 43 respectively.

The paired sample *t*-test showed a significant difference between the pre and post score for the concepts and the concept maps. For the concepts, the mean pre score was 2.92 (SD=1.93, N=12) and the mean post score was 8.92 (SD= 4.30, N= 12), with t (11) = -4.78, p= 0.001, α= 0.05. Since, 0.001< 0.05, the null hypothesis is rejected. In the concept maps, the mean pre score was 8.67 (SD=3.87, N=12) and the mean post score was 24.42 (SD= 10.86, N=12), with t (11) = -4.73, p= 0.001, α= 0.05. Since, 0.001 > 0.05, the null hypothesis is rejected

4.3.4 Displacement I Lesson: In Table 3, the mean and the median for the pre score both had a value of 3. The data was negatively skewed with a value of 0.964. The minimum and maximum scores were 1 and 6 respectively. The post score, showed the mean at a value of 5.14, with the median slightly lower at 5. The skewness had a value of 0.708 which indicates that the values were negatively skewed. The minimum and maximum values were 3 and 8 respectively. Even though the skewed values were negative, the post value showed a decrease, indicating a decrease in concept scores.

In Table 4, the pre score for concept maps, the median (7) was slightly lower than the mean (7.14), which indicates the data was positively skewed with a value of -0.737. Both the minimum and maximim scores were 1 and 11 respectively. Whereas, the mean and median were 12.14 and 12 for the post scores, respectively. The minimum and maximum scores were 3 and 17 respectively. The skewness value was -1.20 indicating the data was positively skewed. In the second lesson entitled 'Displacement I' it is important to note there was a poor attendance, with 7 students attending out of a class of 16.

The paired sample *t*-test revealed no significant difference between the pre and post concepts and the pre and post concept maps. For the concepts, the mean pre score was 3.00

(SD=1.63, N=7) and the mean post score was 5.14 (SD= 1.77, N= 7), with t (6) = -2.17, p= 0.073, α= 0.05. Since, 0.073 > 0.05, the null hypothesis is accepted. In the concept maps, the mean pre score was 7.14 (SD=3.53, N=7) and the mean post score was 12.14 (SD= 4.71, N= 7), with t (6) = -2.03, p= 0.088, α= 0.05. Since, 0.088 > 0.05, the null hypothesis is accepted.

4.3.5 Tarnishing Lesson: In Table 3, the pre score had a mean of 3.5 and a median of 3. The skewness value was at 0.358, indicating a negative skewness. The minimum and maximum scores were 1 and 7 respectively. The post score had the same mean but with a median of 3.50. Both mean and median were the same value, with a skewness of 0.131, indicating most of the values were to the right of the mean. The maximum and minimum scores did not change.

In Table 4, the pre score had a mean value of 7.57 and a median of 6.5, with a skewness value of 1.21, indicating it was negatively skewed. Minimum and maximum values were 3 and 19 respectively. However, the post score, had a mean of 8.36 and a median of 7. The values were negatively skewed with a value of 0.608, even though the mean was more than the median. The maximum and mimimum values were 7 and 1, in that order. While both pre and post skewness values for both concepts and concept maps were positive, there was a decrease in values. This indicated a decrease in scores and thus understanding.

From the paired sample *t*-test, there was no significant difference between the pre and post scores for both the concepts and the concept maps. For the concepts, the mean pre score was 3.50 (SD=1.65, N=14) and the mean post score was 3.50 (SD= 2.17, N= 14), with t (13) = 0.00, p=1.00, α= 0.05. Since, 1.00 > 0.05, the null hypothesis is accepted. In the concept maps, the mean pre score was 7.57 (SD=4.50, N=14) and the mean post score was 8.36 (SD= 6.34, N=14), with t (13) = -.490, p= 0.632, α= 0.05. Since, 0.632 > 0.05, the null hypothesis is accepted.

Overal, the lessons, Physical properties and Bonding in Metals, Displacement II and Rusting showed a significant difference in scores which indicated an improved understanding. While Displacement I and Tarnishing lesson showed no significant improvement.

4.3.6 Qualitative Analysis of Concept Maps:

A qualitative analysis was done for the concept maps constructed from the five lessons. The information gathered from the maps was categorized into themes per lesson. A summary of the pre-and post- concept maps is summarized into categories for each lesson (See Appendix H).

From analyzing the concept maps constructed by students from five lessons, it was found that students had their own concepts or ideas about types of particles, types of changes that took place, observations, explanations for their observations, properties, bonding in metals and examples. Some of these concepts did not line up with scientific ideas and were either rectified in the post concept maps (POMS) or remained the same when compared with the pre-concept maps (PRMS).

4.3.6.1 Physical properties and Metallic bonding in Metals lesson

The following categories emerged in this lesson; properties, structure, bonding and particles, explanation and examples.

Properties: The only physical properties identified were electrical conductivity, heat conductivity, malleability, state and reflection of light.

Electrical conductivity:

The majority of the class indicated that metals conduct electricity (students A, B, C, D, E, F, G, H, I, L, M, O and P in the PRMS and students A, B, C, D, E, F, G, H, I, L, M and N in

POMS).While a few incorrectly stated that the *atoms* that make up the metal are the electrical conductors (students A, L and N in the PRMS only). However in the post concept maps (POMS) 0% held this belief.

Heat conductivity: Students A and P in the PRMS identified this property which doubled in the POMS (students B, D, N and P). Also, a low number of students also recognized that metals expand when heated in PRMS (students E, N and P) while only students N re-stated this in the POMS.

Malleability: Students C, H and K stated in the PRMS that metals can be re-shaped without changing the shape of the atoms, while in the POMS more students held this belief (students A, B, D, G, H, I and K).

State: Students B, D, F, H, J, M and N showed in the PRMS that *metals exist naturally as solids*. This was corrected in the POMS where no students held this belief. From the summary table (See Appendix H) only student O believed that metals can exist in a gaseous state in the PRMS, whereas in the POMS students A, C, D, F, I, L, M and N mentioned this property. Students C, G, O and P stated in the PRMS that metals can exist as a liquid and a solid. However, in the POMS, students C, D, F, G, N and P stated that metals can exist as a liquid, while students C, D, F, G and P stated that metals can exists as a solid. Only one student stated in the POMS that metals exists as a solid at room temperature.

Reflection of light: Students D and P were able to state in the PRMS that metals reflect light. This response in the POMS increased by only one student. Interestingly, students N in the PRMS stated that metal atoms reflect light and in the POMS students E, K, M and N held this belief, a *misconception* which seemed to emerge at the end of the lesson.

Structure: There were some misconceptions present about the structure of the metal. In the POMS, student K believed that metals have room between the atoms, while student L in the PRMS thought that the solid atoms stick together. Student K also believed in the POMS that the room between the atoms was filled with positive and negative charges. While student O stated in the POMS:

> Atoms in metals are compact and overlap and have a lattice structure and becomes positively charged and electrons move through atoms and are negative.

The student was accurate in stating the atoms are compact but was not specific in saying that it is the outer shells that overlap and not the atoms. Student didn't expand on how the positive charge comes about.

Type of bonding and particles: There were a lot of misconceptions here. When it came to the type of bonding in metals and bonding, students thought that metals contained ions or molecules and these particles were held together by magnetism or ionic bonding. Students stated the following in the concept maps:

> Student N (PRNS) - Atoms are together by ionic bonds.
>
> Students E and M (PRMS) and D and K (POMS) – Ionic bonding is found in metals.
>
> Student J (PRNS and POMS) – The type of bonding has positive ions and negative ions.
>
> Student B (PRNS) – Ions in metals are held together by ionic bonds.
>
> Student C (PRNS) and H (POMS) - Positive metal ions and negative electrons which move around the solid.
>
> Students E, I and J (PRMS) – Molecules are held together by magnetism.
>
> Student M (PRMS) – Magnetism found between positive and negative atoms.

Student C (POMS) – Metallic bonding where molecules were held together by magnetism.

Student E (PRMS) – Ionic bonding … atoms being held together by ionic bonds.

However, some students made some scientifically accurate statements:

Students A, B, E, F, K, L, M and N (PRMS) and B, E, F, H, I, O and P (POMS) - Metal consists of atoms.

Students I, J and N (PRNS) and H, J, K and N (POMS) - Metals contain a sea of electrons.

Students D and L (PRMS) and C, H, I and L (POMS) – Metals consists of positive metal ions and negative electrons.

Students B, F, G, H, J and O (PRMS) and B, C, D, E, F, G, I, J, L and O – Metallic bonding found in metals.

Students H (PRMS) and A, B, E and L- Atoms are bonding to surround atoms of the same kind.

Students B, C and E (PRMS) and A, B, E, H and P (POMS) – Chemical bonds hold atoms together.

Explanation:

Electrical conductivity: Students A, B, D, E and M (PRMS) identified that the sea of electrons is responsible for electrical conduction in metals, while students G, K and M along with the A, B, and E had this belief in the POMS. However there were some misconceptions about how metals conduct electricity, most of which indicated that atoms can move. The following statements supported this:

Students B (PRMS) and C (POMS) – Metals conduct electricity due to atoms slipping over their neighbours and moving through the solid.

Student D (POMS) – Atoms move through the metal to transport electricity.

Student C – Metal atoms are electrical conductors.

Student B – Conduction is also due to the overlapping of electrons.

Heat conductivity: Only student B in the POMS was able to explain that metals conduct heat because the atoms are closely compacted that causes heat to be easily transferred through the metal. However, there were students who held misconceptions:

Students A, E and K (PRMS) and K (POMS) - Heat expands metals which cause atoms to become bigger/ change shape.

Student D (POMS) - When heated, atoms move through the metal to transport the electricity.

Students M and P (PRMS) – Bonds melt when heated due to atoms breaking apart.

Malleability: Both students failed to correctly identify that stress causes atoms to roll over each other without breaking their metallic bond. Instead, student C (PRMS) stated that metals have the ability to be re-shaped when heated because the heat causes the atoms to loosen the bonds. While student K (PRMS) stated that metals can change shape because atoms are separated.

State: With respect to the state in which metals can exist, student K in the PRMS stated that atoms are stuck together which created a solid state. Whereas students A, L and M in the POMS believed that when metals are heated to high temperatures it can exists in a gas state.

Examples: Students H, I and P (PRMS) stated that iron is a type of metal, while students A, E, G, I, L and P believed this in the POMS. Steel, copper and brass were listed as an example in both the PRMS and the POMS. Student P also identified foil as an example in the POMS and student G in the PRMS stated that metals are a form of iron, a clear misconception.

4.3.6.2 Displacement I lesson:

Type of particles: In the Displacement I lesson, the class attendance on that day was poor, with a total of 7 students out of a class of 16. In the PRMS, students B and I correctly stated that type of particles found in metals were atoms. These students maintained this belief in the POMS, along with students D, G and J. Students I, J and M also correctly identified that ion particles are found in salt solutions in the PRMS. Students I and J re-stated this in the POMS, along with students B, D, and G. Student M did not maintain this belief. In the PRMS, student J also believed that atoms are present in salt solutions, while ionic particles and molecules were present in metals. These erroneous concepts however, did not appear in the POMS.

Type of change: The only time students identified the reaction as a displacement was in the POMS. Students B and M mentioned that the reaction taking place was a chemical reaction only in the PRMS but no link was made to the displacement reaction being a chemical reaction. Both concepts were separate. Student I was able to construct a word equation for the reaction in the PRMS while students B, D and M along with I was able to do so in the POMS.

Observations: Students were supposed to observe a change in the appearance of the metal and the blue salt solution. Student B in the PRMS made the observation of the metal losing its shiny appearance while this was stated in POMS by students C, D, I and M. Students B, C, I and M stated the loss of colour in the salt solution in the PRMS, however, only students I and M maintained this belief along with student D in the POMS. Only student C thought the solution got darker in both maps. Students C, D, I and M referred to the metal being dissolved in the salt solution in the PRMS (which implies a physical change taking place). Only student C re-stated this in the POMS. Students B and C in the PRMS believed that the metal was deteriorating whereas in the POMS only student B maintained this belief at the end of the lesson.

Explanation: Students gave explanations for their observations in the POMS as oppose to the PRMS. However, most of the explanations given in the POMS were misconceptions, which meant students still left the class not fully understanding the reaction. Some of these misconceptions were:

1. Metal deterioration was due to the loss of sulphate to create magnesium sulphate on the outer part of the strip.
2. There was a loss or gain or particles.
3. Copper displaced the magnesium to make copper metal.
4. Copper (II) ions change from ions to metals.

The first misconception implies the metal is breaking down because there is a loss of sulphate. In the third misconception listed, it is implied that copper is more reactive than magnesium, although the word *'reactive'* is not used. Also, the type of particles present in the metal formed was not stated in the fourth misconception. However, student D correctly stated in the POMS that magnesium displaced the copper to make magnesium sulphate, while student M was able to state that magnesium is extremely reactive, however the student went on to say in the POMS that this was responsible for the colour change. This was not a full explanation for the colour change. One misconception stated in the PRMS by student B, that the loss of blue colour was due to the metal layer being stripped away did not appear in the POMS.

Examples: One student in the POMS was able to give another example of a displacement reaction:

Student C: Displacement reaction between copper metal and silver nitrate.

<u>4.3.6.3 Displacement II lesson:</u>

In the Displacement II lesson, the attendance to class was a total of 15 which was twice as much students present compared to the Displacement I class.

Type of particles: In the PRMS, students A, B, D, F, G, I, J, L, N, O and P correctly stated that the metal contained atoms and the acid contained ions. Only students A, B, D, G, I, J, L, O and P re-stated this in the PMS, along with students C and H. However, there were a few students who had some misconceptions in the PRMS, some stated that:

Student C- Metal contains ions….acid contains atoms.

Student N- Metal contains molecules.

Student C was able to correct these misconceptions made about the particles involved. Student G incorrectly stated in the POMS that the salt produced contained atoms.

Type of change: Only students B and C stated that the reaction between metals and acid was a displacement reaction in the POMS. No other students explicitly named this reaction in the PRMS or in the POMS. Students E, F and M recognized this as a chemical reaction in the PRMS, while students B, H and I stated this in their POMS. Only student H was able to write a word equation for the reaction in the PRMS. This number increased to 5 in the POMS, with students A, B, C and D, along with student H.

Observations: Only student B stated that the metal and the acid remained the same in the PRMS. Also in the PRMS, students B, C, D, G, E, H, I, J, L, M, N, O and P mentioned effervescence being observed. This decreased in the POMS, with only students B, D, E, H, I, J, L, M and O maintaining this observation. Students L and P stated in the PRMS that the metal dissolved in the acid, only student L restated this in the POMS.

Explanation: Only seven students provided explanations in the concept maps, some of which were misconceptions. Fairly accurate statements, all of which showed up in the POMS were:

> Student B- Magnesium displaced the hydrogen to make magnesium chloride.
>
> Student O- Hydrochloric acid contains hydrogen, when reacted hydrogen formed a gas and was replaced by magnesium.
>
> Student P- The atoms in the metal turned to ions which make a soluble metal salt.

Student D was able to identify that the reaction between the acid and the metal caused the effervescence but did not go on to say what the effervescence meant. However, students C, F and J in the PRMS and only student J in the POMS was able to explain that the effervescence meant that a gas was produced. While student G in the PRMS and students F, M and P along with student G in the POMS went on to state that the gas produced was hydrogen gas.

However, there were some inaccurate concepts made, all of which showed up in the POMS and not in the PRMS. Some misconceptions were:

> Student E- Hydrogen gas formed from atoms and ions.
>
> Student E- Particles change into different particles- to soluble ions while hydrogen atoms changed to magnesium and the hydrochloric acid change to chloride both forming magnesium chloride.
>
> Student I- Atoms in the metal and the ions in the acid were displaced.
>
> Student M- Reactants caused the acid to lose chloride ions which was seen through intense and immediate effervescence.
>
> Student O- Atoms when reacted formed into ions creating a magnesium chloride.

Student P- Ions in the acid turned into atoms which give off hydrogen gas.

Student E showed uncertainty in the type of particles from which hydrogen gas is formed. Also, the student also indicated that one named particle would turn completely into a different named particle or substance altogether. Student I suggested that displacement took place in both the metal and the acid. While student M was able to describe the rate of the reaction. Student O stated that the metal atoms turned into ions to create magnesium chloride, but there was no mention or link made as to where the chloride ions came from to form this salt. Also, student P was not clear about which ions in the acid that turned to atoms to give the hydrogen gas. Explanations were either inaccurate, vague or incomplete.

Test for hydrogen gas: Only two students mentioned the test for hydrogen gas in the POMS only. Student D stated that a glowing splint 'outed' with a popping sound as oppose to a lighted splint and student M stated that a lighted splint made a popping sound but did not mentioned that the splint extinguishes.

Example: Student D used the example of opening a soft drink as an example of the reaction. While the example does display effervescence, there is no chemical reaction taking place in this example.

<u>4.3.6.4 Tarnishing lesson:</u>

In the tarnishing lesson, the categories that emerged were type of particles, type of change, observations, explanation and examples. The attendance to class was a total of 14.

Type of particles: Few students were able to correctly identify the particles present in metals, students D and M from PRMS and students F and P, along with students D and M from the

POMS. In addition, only student B identified that oxygen contains atoms from the PRMS and students D, F and M from the POMS. Only student M stated in the POMS that the product formed was an ionic compound. There were also misconceptions about the particles present. Some were as follows:

> Student P: Oxygen contains molecules.
>
> Student B & F: Metal contains ions.

While oxygen gas contain molecules, the oxygen itself is made up of atoms.

***Type of change*:** Students A, B, E and M were able to identify that a chemical reaction had taken place, both in the PRMS and the POMS. However, student B described the reaction as tarnishing in the PRMS, while student P made this statement in the POMS. Some thought that what had taken place was a physical change (students B, F, D, L and P in PRMS and students F, D, L and P in the POMS). Only student D recognized this as an oxidation process but did not specify which type of oxidation and only B in the POMS constructed a word equation for the reaction that took place.

Observations: Students A, B, E, F, D, M and P in the PRMS were able to state a difference in the appearance of the metal by stating the metal was discoloured, however only student A re-stated this in the POMS. Students B, E, D and L in the PRMS implied that the metal was shiny before the reaction, while only students B and L maintained this belief at the end of the lesson. Only student E commented on the mass of the product, indicating that it would be more.

Explanation: Some of the students that stated that change was physical explained this by stating the following:

Student B: Physical change due to discolouration.

Student D: No new substance formed because the metal itself doesn't change just the 'look' of it.

Student L: There was a change but the object remain the same.

Student B did not identify colour change with chemical change. The same student who was able to identify that there will be an increase in mass, explained that the increase was due to the metal bonding with the oxygen in the POMS. Some students gave explanations for what occurred:

Student F & P (POMS) - Metal and oxygen atoms combine to form metal oxide.

Student M- Oxygen cause the metal object to discolour

Student B stated that the bond formed was ionic but did not go on to elaborate on its formation.

Examples: Two students were able to give examples of tarnishing. All examples occurred in the POMS are as follows:

Student D- Coins and silver tarnish

Student P- Metal oxide- aluminium oxide and copper when it tarnished it looks attractive.

4.3.6.5 Rusting lesson:

In the rusting lesson, the categories that emerged were metals involved, type of change, conditions for rusting, observations, explanation, prevention methods and examples. The attendance to class was a total of 12.

Metals involved: Students identified iron, steel and metals as the metals taking part in the rusting process. Metals being very vague. Students A, E, F, J, L, M, N and P in the PRMS identified iron as the metal that undergoes rusting, while only students C, D, L, M and N stated this in the POMS. Students E, F and N identified steel as a metal that would rust in the PRMS, while N was the only student to re-state this. Students C, D, I, J, L and N in the PRMS stated that metals rusted with students L and N in the POMS re-stated this. From these statements it is seen that student L and N maintained the belief that iron, steel and metals all rust. Metals being incorrect.

Type of change: Chemical change, physical change, wet oxidation and corrosion were identified in the concept maps. Students A, F, G and J recognized rusting as a chemical change in the PRMS, while students C, E, I, L, N and P in the POMS, along with the students from the PRMS, stated rusting is a chemical change. Students C, D, E, J, L, M and N however stated in the PRMS that rusting is a physical change. Only students D and J re-stated this in their POMS. Students C and I listed rusting as a type of wet oxidation in the POMS. In the POMS, students D, E, G and L stated that rusting is corrosion. From these statements, student J at the end of the lesson classified rusting as both a chemical and a physical change. Student L recognized that rusting was a chemical change and that it fell under the category of corrosion but failed to state what type of corrosion. While students C and I stated that rusting is a chemical change and is a type of wet oxidation.

Conditions for rusting: An overwhelming majority indicated that moisture or rain as condition needed in rusting (students A, C, D, E, G, I, J, L, M, N and P in the PRMS and students A, C, D, F, I, J, L, N and P in the POMS. Students E, G and M did not re-state this in the POMS. Student I explicitly stated in her PRMS that metals rust when wet. Oxygen or air was also identified as a condition (students C, D, E and J in the PRMS and students A, F, I, L, N and P along with C, D and J in the POMS). These students in the POMS stated *both* conditions which are required for rusting. However, also mentioned were salts, time, impurity, heat and environment as other conditions required for rusting to occur. Students who stated environment, impurity and heat in the PRMS as conditions did not re-state this in the POMS.

Observations: More than half the class indicated that rusting decreases the mass of the metal in the PRMS (students A, C, E, F, L, M and P) and fewer students stated this in the POMS (students L and P). A small number had opposing views in the POMS (students A, E, F, G and I) about this and said the mass would increase. It can be seen that students A, E and F changed their belief that rusting decreases the mass of the metal to an increase in the mass of the metal. Students D and M in the PRMS believed that there would be no change in mass, only student D maintained this belief in the POMS. A new substance was also said to be formed which supports the statement that students made about rusting being a chemical change. One student described the rusting of the metal as rotting in the PRMS only.

Explanation: Students who stated there would be a decrease in mass, the explanations given were:

> Students A, C & P- Decrease in mass because rusts breaks down the metal or decays it…the metal is being eaten up by the rust.
>
> Student L: Decrease in mass because item is being dissolved when exposed to moisture.
>
> Student M: Decrease in mass because iron reacts with oxygen in the air, does not weigh anything but the process of rusting will cause the bonding to weaken.

Students A, C and P actually believed that rusts was something apart from the metal itself which breaks down the metal. The students who stated that rusting is a chemical change, the following statements were made:

> Student A: New substance made with all the ions and iron combined.

Student C: Iron atoms go into solution to form iron ions.

Student J: Chemical change made up of iron…

Student L: Oxygen dissolves in water to form hydroxide ions which reacts with iron to form iron hydroxide.

Only student M was able to explain the rusting process. While student P believed that heat causes the outer layer of the metal to weaken and break apart causing it to rust.

Prevention methods: Oiling and painting were the two common prevention methods identified (students A, C, G, I, J, L, M and N in the PRMS and students C, D, E, F, G, J, L, N and P in the POMS). Other methods mentioned only in the POMS were tinning (students C, D, F, J and N), galvanizing (students C, D, E, F, J and P), alloying (students C, D, E, F, J and N) and electroplating (students D, J and N). Only student J was able to identify all six prevention methods. Even though these methods were correctly identified in the concept maps, the students failed to explain how these methods prevent rusting. A few students listed keeping away from the open or wet and using citric acid as prevention methods.

Examples: No examples were given in the PRMS and the POMS.

4.3.7 The performance of form four Integrated Science students academically using concept maps

A Summative Conceptual Achievement Test (SCAT) was administered at the end of the unit after the intervention was implemented (only 14 students were present for the test). Figure 6 illustrates that zero students were able to attain an A grade (75% and over). One student was able to receive a B grade (65%-74%), while 6 students obtained a grade C (55%-64%). Students receiving a grade D (45%-54%) totaled a number of five, while two students achieved an E grade (<45%). From the bar chart, it can be seen that the majority of students obtained a percentage between 64% and 45%.

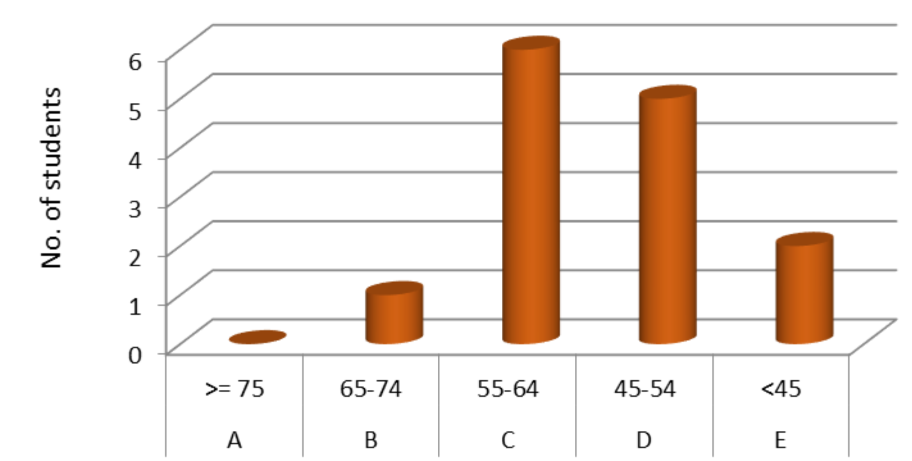


Figure 6. **Bar chart illustrating the grades obtained by students**

4.3.8 Students' Conceptual Understanding of Reactivity of Metals using the SCAT:

Three phases of analysis of the SCAT scores was also used in the conclusions about the students' conceptual understanding of reactivity of metals. In the first phase, the total number of student responses in the SCAT were calculated (See Table 5). In the second phase, four subscales were constructed for the SCAT items and analysed. In the third phase, the students' selections of answer options for each item (in each subscale) were examined and conclusions about student knowledge and understanding were drawn from each item.

PHASE 1- Total number of student responses

Table 5

Summary of the student responses of the SCAT

Item No.	**Part I** **A**	**B**	**C**	**D**	**Part II** **1**	**2**	**3**	**4**	
1	6	4	4	-	1	3	7	3	
2	1	12	1	-	2	11	1	-	
3	8	6	-	-	5	0	2	7	
4	3	11	-	-	7	2	2	3	
5	0	2	12	-	4	5	6	-	one no response part 1
6	2	4	2	6	0	3	8	3	
7	2	5	6	1	0	3	5	6	
8	8	0	4	2	2	4	3	4	one no response part 2
9	0	0	1	13	0	0	0	14	
10	13	0	1	0	7	6	1	0	
11	3	3	7	0	0	11	3	1	one no response part 1
12	10	3	1	0	0	2	2	10	
13	10	2	1	1	4	3	2	4	one no response part 2
					Correct Explanation		**Incorrect Explanation**		
14	0	14	0	0	12		2		
15	13	1	-	-	11		3		

Note: The correct response is underlined
- No option available

PHASE 2- Subscales

The items in the SCAT were categorized in the following subscales:

1. Structure & Properties of metals items (2, 3, 4, &10)
2. Displacement items (5, 6, 7, 12, 13, 14 & 15)
3. Tarnishing items (1)
4. Rusting items (8, 9 & 11)

PHASE 3- Subscale analysis

4.3.8.1 Structure & Properties of metals items:

Table 6

A summary of structure and properties of metal item responses

		Part I				Part II			
Item No.	# of responses	**A**	**B**	**C**	**D**	**1**	**2**	**3**	**4**
2	#	1	12	1	-	2	11	1	-
	%	7.14	85.7	7.14	-	14.2	78.5	7.14	-
3		**A**	**B**	**C**	**D**	**1**	**2**	**3**	**4**
	#	8	6	-	-	5	0	2	7
	%	57.1	42.8	-	-	35.7	0	14.2	50
4		**A**	**B**	**C**	**D**	**1**	**2**	**3**	**4**
	#	3	11	-	-	7	2	2	3
	%	21.4	78.5	-	-	50	14.2	14.2	21.4
10		**A**	**B**	**C**	**D**	**1**	**2**	**3**	**4**
	#	13	0	1	0	7	6	1	0
	%	92.8	0	7.14	0	50	42.8	7.14	0

Note: The correct response is underlined
- No option available

In Table 6, item 2 assesses students' knowledge and understanding on heat conductivity which is a property of metals. Twelve (85.7%) students were able to identify that the metallic object is a good conductor of heat and out of those 12 students, 10 (71.4%) in part II were able to choose the correct explanation for their answer in part I. Two (14.2%) students were not able to recognize that the metallic object (pot spoon) is a good conductor of heat and instead thought that the object became hot because particles expand on heating or that hot surrounding air combines with the object. Overall, the majority of the students displayed an understanding in the properties of metals in this item.

Items 3 and 4 assessed students' understanding on particles present in metals in its natural state and particles in an aqueous state. In item 3, 6 (42.8%) students were able to identify that magnesium atoms are the type of particles present in magnesium ribbon by choosing Mg while 8 (57.1%) chose Mg^{2+} which indicates that these students believe that ions are present in magnesium ribbon. Out of these 8 students, 5 (35.7%) justified their answer by explaining that ions are charged species with the correct charge for magnesium. While ions are charged species, magnesium metal contains atoms in its natural state and for this reason their response was incorrect. In part II, 7 (50%) students were able to correctly choose the explanation for their answer in part I; that particles in magnesium metal atoms are neutral thus they are not charged species. Five of these students correctly answered part I. There were 2 (14.2%) students (one of whom chose Mg^{2+} for part I and the other Mg) who believed that the magnesium atom has a positive nucleus for part II. While it is correct that the nucleus is positive it does not explain either of the choices in part I. No student chose the reactivity of the magnesium atom as an explanation for this item, this indicates that students recognize that this is not a plausible explanation.

In item 4, 11 (78.5%) students were able to correctly identify Ag^{+} as the correct symbol for silver in silver nitrate. This indicated that students recognized that ions are available in aqueous solutions. However, out of the 11 students, only 7 (50%) gave a correct explanation in part II. A low number of 3 (21.4%) students thought that atoms are present in an aqueous solution of silver nitrate and chose the symbol Ag in part one. Two (14.2%) of these students in part II justified their answer and chose the explanation that the particles in silver (in silver nitrate) are neutral atoms. Also, two (14.2%) students in part II both of whom answered part I correctly, indicated that the symbol for silver in the aqueous solution was Ag^+ because it has a positive nucleus. And 2 (14.2%) other students claimed that the reason for their answer in part I was due to high reactivity of silver ion. The four students altogether don't show a clear understanding of particles in aqueous solutions.

In item 10, 13 (92.8%) correctly identified that when a metallic object is placed in an electrical circuit the bulb will light only one students claimed it will blow. However in part II, of those 13 students only 5 (35.7%) students were able to identify the correct explanation in part II, that metals contain a 'sea' of free-moving electrons which are responsible for metals being an electrical conductor, while 7 (50%) students stated that the metal atoms themselves are good electrical conductors and one student who was able to correctly identify the answer in part I was the only student who claimed that metal conduct electricity due to movement of atoms and their ability to slip over other neighboring atoms. These were very erroneous explanations.

4.3.8.2 Displacement items:

Table 7

A summary of Displacement item responses

		Part I				Part II				
Item No.	# of responses	**A**	**B**	**C**	**D**	**1**	**2**	**3**	**4**	
5	#	0	2	12	-	4	5	5	-	one no response part 1
	%	0	14.2	85.7	-	28.5	35.7	35.7	-	7.14%
		A	**B**	**C**	**D**	**1**	**2**	**3**	**4**	
6	#	2	4	2	6	0	3	8	3	
	%	14.2	28.5	14.2	42.8	0	21.4	57.1	21.4	
		A	**B**	**C**	**D**	**1**	**2**	**3**	**4**	
7	#	2	5	6	1	0	3	5	6	
	%	14.2	35.7	42.8	7.14	0	21.4	35.7	42.8	
		A	**B**	**C**	**D**	**1**	**2**	**3**	**4**	
12	#	10	3	1	0	0	2	2	10	
	%	71.4	21.4	7.14	0	0	14.2	14.2	71.4	
		A	**B**	**C**	**D**	**1**	**2**	**3**	**4**	
13	#	10	2	1	1	4	3	2	4	one no response part 2
	%	71.4	14.2	7.14	7.14	28.5	21.4	14.2	28.5	7.14%
		A	**B**	**C**	**D**	**Correct Explanation**		**Incorrect Explanation**		
14	#	0	14	0	0	12		2		
	%	0	100	0	0	85.7		14.2		
		A	**B**	**C**	**D**	**Correct Explanation**		**Incorrect Explanation**		
15	#	13	1	-	-	11		3		
	%	92.8	7.14	-	-	78.5		21.4		

Note: The correct response is underlined
- No option available

In items 5, 6, 7, 12, 13, 14 and 15 all looked at reactivity of metals on the principal of displacement reactions. Item 5 dealt the displacement reaction between iron and hydrochloric acid. Twelve (85.7%) were able to correctly account for the change in the colour of the solution due to the combination of iron with chlorine to form iron (II) chloride. However, 2 (14.2%)

students claimed that the colour due to the fact that iron is light green in solution. Although the response to part I was good in terms of students' knowledge, when asked to choose an explanation for their answer only 4 (28.5%) students were able to correctly identify the presence of iron ions attributed to the colour of the solution and of those responses only two students answered part I correctly. The remaining 10 students for part II chose incorrect explanations all of whom selected the correct in part I. Five of those students selected the explanation that said when iron and chloride atoms combine they become green in colour, while the other 5 students thought that when iron atoms are dissolved in hydrochloric acid they become green in colour. While the majority of the class was able to select the correct response for part I they were unable explain why the solution turned green. Most of whom indicated a misconception that the atoms themselves turn or possess a colour.

Item 6 which is an extension of item 5, looked at the gas produced between the metal and the acid. Six (42.8%) students were able to identify that reactive metals produce hydrogen when added to dilute acids. While 4 (28.5%) thought that acids produce the gas when they react with all metals, 2 (14.2%) believed that the gas is discharged from the iron itself (which suggests that the students think that the hydrogen is part of the metal) and the remaining 2 believed that the gas is produced when water molecules decompose. When students had to choose a reason for their answer in part I, 8 (57.1%) students correctly chose the explanation that iron is more reactive than hydrogen and thus will displace it from the acid. Out of these 8 students only 5 answered part I correctly. Three (21.4%) students thought that the hydrogen was produced because it is highly reactive due to its one valence electron and the remaining 3 students claimed that the size of the atoms causes displacement to occur, the bigger atom being iron. While iron atoms did displace the hydrogen ions from solution it did not do this due to size but reactivity.

Item 7 is another displacement reaction, this time involving a metal and a salt solution. When students were asked in part I to say why there was a colour change in the solution, 6 (42.8%) correctly chose the response that the salt solution (copper II sulphate) completely reacted. While 5 (35.7%) claimed that because zinc (a metal) is more reactive than copper (II) sulphate (a salt solution), 2 (14.2%) students claimed the colour change was due to copper forming a precipitate while one student believed that when zinc is placed in the salt solution it dissolves which will result in a colour change. These 8 students selected responses which did not indicate why the solution turned colourless. When asked to select a reason for their selected responses, 6 (42.8%) students selected a response which indicated that the presence of the copper ions were responsible for the colour of the solution. Four of these students' answers in part II correctly corresponded with their answer in part I. They recognized that all the copper (II) sulphate reacted completely which shows that they understand that absence of copper ions which is responsible for the solution being coloured. Thus no copper ions means a colourless solution. Whereas the remaining 8 students reasons for their answer in part I were as follows: 3 (21.4%) students explained that zinc loses electrons more readily than copper and 5 (35.7%) students claimed that the copper ions were blue which formed into reddish-brown copper atoms. While the copper ions did change to atoms in the reaction neither actually has a colour.

In item 12, another displacement reaction looked at the reaction between copper wire and silver nitrate solution. Ten (71.4%) students were able to correctly identify that the deposits in the reaction was in fact silver, one student incorrectly identified the white solid as copper nitrate even though the equation explicitly identifies it as a solution and 3 (21.4%) students claimed the deposits were that of copper which is incorrect since copper has a red-brown colour. Ten (71.4%) students correctly selected the right explanation in part II, 8 of which answered part I correctly. Two (14.2%) students in part II chose the explanation that evaporation of the silver nitrate occurred causing white deposits to form. These students however, answered part I correctly but showed little understanding when answering part II. Also, 2 other students said that the white deposits were due to copper corroding. Both of these students said that the white deposits was that of copper in part I. This showed that these two students do not have a clear understanding of what is occurring in the reaction (even though the word equation was given).

Item 13 was answered very poorly. A lot of students failed to realize that this item was also a displacement reaction. Ten (71.4%) students thought the orange-brown colour on the nail was rust. Only 2 (14.2%) students correctly identified the colour due to copper deposits. They were not able to recognize that this was a displacement reaction and that iron was more reactive and displaced copper ions from its salt solution. One student said the colour was due to the copper ions connecting with the iron nail and another student claimed that the nail was breaking down in the presence of the salt solution. When students were asked to explain their response from part I, 3 (21.4%) students were able to correctly state that the deposits were due to the iron displacing copper ions out of solution because it was more reactive.

However, 10 students did not select the correct option for part II. Four (28.5%) students believed the deposits were due to the iron nail rusting in the salt solution and the same number of students thought that the deposits were attributed to a chemical change occurring between the nail and the salt solution, while 2 (14.2%) students said the salt solution combined with the iron atoms on the nail resulting in the deposits to form. Most students probably confused the fact this reaction with rusting because an iron nail was involved and that the orange-brown colour formed.

4.3.8.3 Tarnishing items:

Table 8

A summary of Tarnishing item responses

		Part I				Part II			
Item No.	No.of responses	**A**	**B**	**C**	**D**	**1**	**2**	**3**	**4**
1	#	6	4	<u>4</u>	-	<u>1</u>	3	7	3
	%	42.8	28.5	28.5	-	7.14	21.4	50	21.4

Note: The correct response is underlined
- No option available

In Table 8, item 1 required an understanding that metal oxide has a greater mass than its corresponding metal due to the metal atoms combining with the oxygen molecules. However, only 4 (28.5%) students were able to identify that there would be an increase in mass in part I, while 6 (42.8%) said there would be a decrease in mass and 4 (28.5%) claimed that there would be no change in mass. When asked to give an explanation for their responses, only 1 (7.14%) student was able to choose the appropriate explanation. While 7 (50%) claimed that burning the metal would cause the metal atoms to be separated causing the final product-the metal oxide- to be less dense than the metal itself. Students also showed a clear misconception between the two terms mass and density.

Three students (21.4%) believed that the metal oxide contained molecules which was responsible for a greater mass. This indicates that even though students recognized that the mass is greater, they failed to understand that the compound formed was ionic and did not contain molecules but ions. While 3 (21.4%) students chose the response which indicated that when a metal is heated the atoms in the metal only become heated.

4.3.8.4 Rusting items:

Table 9

A summary of Rusting item responses

		Part I				Part II				
Item No.	No. of responses	**A**	**B**	**C**	**D**	**1**	**2**	**3**	**4**	
8	**#**	8	0	<u>4</u>	2	2	<u>4</u>	3	4	one no response part 2
	%	57.1	0	28.5	14.2	14.2	28.5	21.4	28.5	7.14%
		A	**B**	**C**	**D**	**1**	**2**	**3**	**4**	
9	**#**	0	0	1	<u>13</u>	0	0	0	<u>14</u>	
	%	0	0	7.14	92.8	0	0	0	100	
		A	**B**	**C**	**D**	**1**	**2**	**3**	**4**	
11	**#**	<u>3</u>	4	7	0	0	11	<u>3</u>	1	one no response part 1
	%	21.4	28.5	50	0	0	78.5	21.4	7.14	7.14%

Note: The correct response is underlined

In Table 9, from the responses received in item 8 in part I, no student chose the option stating that the mass of an iron nail would be that same as compared to the mass of a rusted iron nail. Students showed that rusting does have an effect on the mass of the iron nail. Eight (57.1%) students incorrectly chose the response which claimed that the mass of the nail would be less as opposed to the 4 (28.5%) who correctly identified that the rusted nail would be more than the original iron nail. Only 2 (14.2%) claimed that the may would be impossible to predict (response D). When students chose explanations for their answers in part II, only 4 (28.5%) correctly indicated that rust contains oxygen and iron. These same four students chose the correct answer in part I. The eight students that indicated a loss in mass in the rusted nail, all chose explanations which implied a loss in the mass of the nail, except for one student who did not chose an explanation. Ironically, the students who chose response D in part I, both chose the response that the iron from the nail is destroyed in rusting.

Item 9 showed that students had a good understanding about the conditions/factors which affect rusting. An overwhelming 13 (92.8%) students identified the right conditions for rusting in part I, while one (7.14%) did not. However, when asked to give a reason for their answer, all 14 students chose the correct explanation.

Item 11 tested students' knowledge and understanding of sacrificial protection. Only 3 (21.4%) students were able to correctly identify zinc as the metal used in this rust protection technique. However, of these three students only one gave a correct explanation for the metal chosen in part II. The remaining students chose the wrong metal involved in this process; 4 (21.4%) chose tin while 7 (50%) chose copper as the metal used. No students chose lead as the metal used in sacrificial protection. When asked to choose an explanation for the metal chosen, only 3 (21.4%) identified the principal of zinc being more reactive than iron. While 11 (78.5%) claimed that the metal they chose in part I would protect iron if the metal was less reactive. Only one student thought melting point was responsible for sacrificial protection. No students chose cost as their explanation. This question shows that students do not understand the concept behind sacrificial protection.

<u>4.3.9 A cross analysis between Concept maps and SCAT:</u>

The results from the qualitative analysis in the concept maps (See Appendix H) were cross analysed with those from the SCAT (items 1- 13) (See Appendix I). This was done to determine whether or not students reverted to their previous way of thinking or if conceptual change did occur when the SCAT was administered after the unit of work was taught. The subscales used in the SCAT analysis were used as well in the cross analysis.

4.3.9.1 Physical Properties of Metals and Metallic bonding:

Heat conductivity was assessed in item 2. Students C, D, F, G, H, I, J, L, M, N, O and P all identified that the metal pot spoon is a good conductor of heat in part I of the SCAT. When compared with the concept maps, students A, E, N and P (PRMS) and B, D, N and P (POMS) were able to identify heat conductivity as a property of metals. From the SCAT, only students D, N and P maintained heat conductivity as a property of metals towards the end of the unit, while the other students showed an improvement in knowledge of the properties of metals.

However, only student B in the POMS was able to give an accurate explanation for this property. In part II of the SCAT, students C, D, G, H, I, J, L, M, N and O were able to choose the correct explanation that the lattice vibrations and movement of electrons allows for heat conduction. Surprisingly, student B did not choose the correct answer in part I or II of the SCAT. This showed that at the end of the unit of work the student reverted to their original beliefs about this property.

The type of particles present in metals and salt solutions were assessed in items 3 and 4. Item 3 assessed students on their knowledge and understanding of the particles present in metals. In Table 10, students F and H were consistent in their knowledge which was in line with science worldviews. However, students C, G, J and D showed this knowledge only in the SCAT and not in the concept maps. This shows an improvement in their knowledge and that conceptual change took place.

Item 4 in the SCAT assessed students' knowledge on the type of particles present in salt solutions. In Table 10, students B, D, G, H and J not only were able to correctly identify that the type of particles in salt solutions but maintained this belief throughout in the POMS for both lessons to the end of the unit. Comparing the POMS in the *Displacement II lesson,* it can be seen that students I and N did not maintain this belief towards the end of the unit when the SCAT was administered.

Table 10

A summary of the students who responded accurately when assessed on the type of particles present in metals and salt solutions

Criteria being assessed	Assessment tool	Students who responded
The particles present in metals are atoms	Concept maps	*Properties of metals & Metallic bonding lesson*- A, B, E, F, K, L, M & N (PRMS) and B, E, F, H, I, O & P (POMS).
	SCAT (Part A)	C, F, G, H, J & D
The particles present in salt solutions are ions	Concept maps	(i) *Displacement I lesson*- I, J & M (PRMS) and B, D, G, I & J (POMS). (ii) *Displacement II lesson*- A, B, D, F, G, I, J, L, N, O & P (PRMS) and A, B, C, D, G, H, I, J, L, O & P (POMS).
	SCAT (Part A)	B, C, D, G, H, J, L, M, N, O & P

Table 11

A summary of the students who responded accurately when assessed on electrical conductivity

Criteria being assessed	Assessment tool	Students who responded
Metals conduct electricity	Concept maps	A, B, C, D, E, F, G, H, I, L, M, O & P (PRMS) and A, B, C, D, E, F, G, H, I, L, M & N (POMS)
	SCAT (Part A)	B, C, D, E, F, G, H, J, L, M, N, O & P
Electrical conduction is due to the 'sea' of mobile electrons	Concept maps	A, B, D, E & M (PRMS) and A, B, E, G, K, M & O (POMS)
	SCAT (Part B)	B, H, I, J, N & O

In item 10, electrical conductivity was assessed. From Table 11, students B, C, D, E, F, G, H, J, L, M, O and P were able to recognize that the bulb in the electrical circuit will light because the metal object in the circuit is an electrical conductor. When compared with the POMS, it can be seen that these same students held this belief (Student A was absent for the SCAT).

Only students B and O in the POMS gave accurate explanation for electrical conductivity of metals. When compared with Part II in the SCAT, students B, H, I, J, N and O were able to choose a correct explanation. In Table 11, it can be seen that students B and O maintained the correct understanding on electrical conductivity while student H, I, J and N improved in theirs. However, students C, D, E, F, G, L, M and P indicated that the atoms and not the electrons were responsible for this property in the SCAT, some of which (students E, G and M) did not maintain the correct understanding at the end of the unit.

4.3.9.2 Tarnishing :

From the qualitative analysis of the concept maps, only student E mentioned an increase in the mass of the metal due to tarnishing. However, item 1 in Part I of the SCAT (See Appendix I) 4 students (E, H, I and M) correctly chose the response, that the mass of the metal would be greater. These students however in their concept maps (PRMS and POMS) did not indicate anything about mass. Of these 4 students, only student M chose the correct explanation in Part II of the SCAT for this observation. Ironically, student E did not choose the correct explanation in the SCAT, even though a correct explanation was given in the POMS. This student did not maintain this belief towards the end of the unit. The other students at the end of the unit held erroneous views about the mass of the metal oxide formed, in addition to which their concept maps did not indicate anything about mass.

4.3.9.3 Displacement:

Colour change is associated with chemical change. In the Displacement II lesson students E, F and M (PRMS) and B, H and I (POMS) recognized that the reaction taking place between the acid and the metal was chemical. Students B, C, D, E, F, G, H, J, L, M, N and P in item 5 (part I) of the SCAT were able to account for the appearance the green colour when iron reacts with hydrochloric acid which formed a new substance. These student recognized a chemical change had taken place. Only students B and H maintained this belief.

Student I was the only student that indicated in the POMS in the Displacement I lesson that a loss of colour indicated an absence of particles. In the SCAT (Part II), only student E, I, O and P chose the correct explanation that the presence of the ions produce the coloured solution. Thus student I maintained this belief at the end of the unit, while students E, O and P showed a change in their explanation. The other responses incorrectly chose options which stated that the particles themselves had a colour.

Hydrogen gas production: Students C, F and J (PRMS) and J (POMS) were able to state that a gas is produced between a metal and acid. Only students G (PRMS) and F, G, M and P (POMS) explicitly stated that the gas produced was hydrogen. Item 6 in the SCAT assessed students understanding on hydrogen gas production when metals react with acid. Students B, D, E, F, G and P in Part I correctly chose that reactive metals produce hydrogen when added to dilute acids. These students were able to recognize that the metal needs to be reactive in order for hydrogen gas production. From Table 12 it can be seen that student F showed growth in understanding of this concept, from the idea of gas production to naming the gas produced and then finally being able to establish that reactive metals are needed for this to occur.

Table 12

A summary of the students who responded accurately when assessed on hydrogen gas production

Responses	Assessment tool	Students who responded
A gas is produced	Concept maps	*Displacement II lesson*- C, F & J (PRMS) and J (POMS).
Hydrogen gas is produced	Concept maps	*Displacement II lesson*- G (PRMS) and F, G, M & P (POMS).
Reactive metals produce hydrogen when added to dilute acids	SCAT	B, D, E, F, G & P

From the POMS, students B and O were able to explain the formation of the gas from the following statements:

-Student B: …Magnesium displaced the hydrogen to make magnesium chloride.

-Student O: Hydrochloric acid contains hydrogen, when reacted hydrogen formed a gas and was replaced by magnesium.

When students were asked to choose a reason for their answer in Part II of the SCAT, students A, B, C, D, E, F, I, M and P recognized that displacement of hydrogen occurred by a reactive metal. Only student B maintained this belief at the end of the unit as oppose to student O. The other students who chose the correct explanation improved in their understanding since they failed to give explanation for gas production in the concept maps.

Colour change is can sometimes be observed in displacement reactions. Only student I in the POMS was able to give an explanation for the colour change of the solution in a displacement reaction. Item 7 (Part I) in the SCAT (another *Displacement* question), students F, G, I, J, M and P were able to correctly state that the loss of colour in the solution was due to the fact that copper (II) sulphate had reacted completely. When asked to choose an explanation for their answer, student C, G, H, I, J and P chose the correct response, which stated that the presence of the copper ions produce a blue solution. Therefore, when all the solution reacted, there would be no more copper ions and thus a colourless solution. Students C, G, H, J and P showed an improved understanding while student I maintained this understanding of this concept.

Displacement reactions were also assessed in item 12 in the SCAT. Students A, B, C, D, E, F, G, H, I, O and P were able to name the deposit formed when copper reacted with silver nitrate. When asked to choose the correct explanation, students C, D, E, F, G, H, J, M, O and P were able to identify that silver ions were displaced by copper metal to form silver metal. Upon looking at the concept maps, only student D was able to state correctly what was being displaced and it was also due to the metal being more reactive. It can be seen that student D maintained this understanding in the SCAT. The other students who chose the correct explanation in Part II showed an improvement in their understanding.

Item 13 also dealt with displacement, however, compared to item 12, this question was poorly answered. Students did not recognize iron as being more reactive which would be able to displace copper ions to form copper deposits. Only two students (E, P) correctly identified the deposits in part I. Students E, F, and N were able to choose the correct explanation for this reaction. Cross analysing the concept maps, it was seen that no students made observations of metal deposits and thus no explanation followed either. Students still showed no change in their understanding here.

<u>4.3.9.4 Rusting</u>:

In item 8 in the SCAT, students E, F, I and M answered part I correctly, indicating rust weighs more than the nail it came from. In the concept maps, student I (PRMS) and students A, E, F, G, and I (POMS) indicated the same. It is clearly seen that students E, F, and I maintained this belief at the end of the unit. While student M indicated in the PRMS that there would be a decrease in mass. In the SCAT there was a change in this student's belief. The same students who chose the correct option in part I, were the only students that correctly responded in part II when asked to choose an explanation for their answer in part I. Eight other students in the SCAT (part I) indicated that the mass would be less. Some of these students indicated this in the PRMS or did not include it in the concept maps at all.

In item 9 in the SCAT, students were assessed on the conditions required for rusting. Students C, D, E, F, G, H, I, J, L, M, N, O and P except B correctly chose the correct option in part I. Also, all students were able to identify water and oxygen as conditions needed for rusting to occur and in the POMS, students A, C, D, F, I, J, L, N and P indicated rain/moisture and oxygen. It can be seen that students C, D, F, I, J, L, N and P maintained this understanding when the SCAT was administered while students E, G, H and M improved in their understanding.

Students C, D, E, F, J and P in the POMS were able to identify galvanizing as a rust prevention method. In item 11 of the SCAT (Part I), students did not make the connection that galvanizing is sacrificial protection. As a result, only students B, G and O correctly identified zinc as the metal used in this protection method. While no students were able to give an explanation for this method in the concept maps, students C, H and O were able to choose the correct explanation in Part II. These students displayed an improved understanding in the principle behind sacrificial protection. Only student O got both parts correct.

4.4 Students' perceptions of the use of the 5E Learning cycle as a learning tool and its use on understanding

4.4.1 Journals:

Students were asked to write about their perceptions of the 5E Learning cycle with respect to their understanding and its use as a learning tool. Guided questions were used to elicit this information. After the journals (See Appendix J) were reviewed and coded, seven major themes emerged; engaging learning environment, non- engaging learning environment, self-reflection, benefits of teaching strategy, learning style, undesirable aspects of teaching strategy and personal feelings towards science (See Table 13).

Table 13
Table contains categories and codes from journals

Codes	Emerging themes/Categories
Hands- on work Interaction Experiments/practicals/lab work Participating Interactive exercises Questioning Involvement of students Class discussions Class activity Concept maps Multiple techniques *The way the lesson was taught…* Group work	Engaging learning environment
Writing and reading notes *I honestly might not have understood it by just writing notes* *Reading from a text book* *Writing notes to be memorized* *Sit and listen*	Non-engaging learning environment
Assess myself	Self- reflection
Educational Fun/ exciting Broaden perspective	Benefits of teaching strategy

Good foundation Interest in the topic Focus Interest Student autonomy Cleared up misunderstandings Improved memory	
Visual Active Verbal	Learning style
On the spot questioning Complexity of the topic *Loads of information* Length of introduction Confusing introduction Answering techniques Layout of parts of lessons Concept maps	Undesirable aspects of teaching strategy
I don't understand or like chemistry *I am not much of a chem/physics person* *I didn't understand clearly and I don't like chemistry* *Not relevant* Irrelevance of the topic	Personal feelings towards science

[The items in *italics* are invivo quotes]

4.4.2Engaging Learning Environment:

Students mentioned different aspects of the lessons which were beneficial to their understanding, all of which was categorized as an engaging learning environment. Some of their journal entries were as follows in Table 14.

Table 14

Journal extracts for Engaging learning environment

Student	Journal Responses
B	*"…doing the activity and seeing what suppose to take place really gave me a fairly understanding"*
C	*"Because the lesson requested me to be physical…that helped me in my learning and understanding of it"* *"The discussions after each activity was extremely helpful…was extremely beneficial to my learning because it assisted me in ensuring that I had a proper understanding…"*
D	*"…it was physical and interactive…helped me with the understanding of the content"*
E	*"I got hands on activities to which made me understand exactly why certain things are a certain way."* *"I considered the labwork and class discussion beneficial to my learning because it allows me to get hands on learning as well as to be interactive as a class"*
F	*"The discussion after the lab….helped me to understand what was done during the lab"* *"The group activity helped me understand the content taught…"*
G	*"Doing practical work was beneficial and more interaction because I understand more"*
H	*"The class activity helped me in learning because it is very interactive…"*
J	*"The experiments helped me understand the content taught"*
K	*"Doing the labs because it was a better way to explain*
L	*"…when we did the exercise of actually doing what we talking about at first and then after doing that I actually understand a little more better"* *"The discussion part of the lesson helped with my understanding because the things I did not understand before I sometimes get the answer at the end"* *"I believe my understanding of the topic has improved by the way the lesson was taught because it was practical…"*
M	*"The practical part of the lesson helped understand the content because hearing and seeing assisted in applying both made it comprehendable"*
N	*"The practical and the written out word formula helped me to understand today's lesson"*
P	*"I believe the involvement of students into the lesson and the questioning of them about the topic is beneficial to my learning…"*

Students' statements in Table 14 show that the 5E Learning cycle involved hands-on activities, participation, group work, class discussions which as stated earlier in the literature review "makes students aware of their own reasoning by helping students reflect on their activities" (Balci, Cakiroglud, & Tekkaya, 2006). This is supported by a student's statement:

Student M- The multiple techniques made me assess myself…

There was a resounding 'yes' when asked if the way the lesson was taught if it improved their understanding. The reason for an improved understanding according to their responses, was due to an engaging learning environment. Some of their responses were:

Student B- …it has improved because of the hands on experience and open discussions with the class.

Student B- Yes I do believe that the understanding of the topic has improved thus far because of all the practical aspects of the lesson and the hands on activities.

Student D- So because it was interactive and physical it made me pay attention which has improved my understanding of the topic.

Student E- …it improved greatly because the activities made the class a lot more interactive…

Student E- …with the class interaction and lab it was very hands on and helpful which made me understand more…

Student I- Yes because doing a practical lesson made the topic a lot more interesting.

Student L- Yes, I believe my understanding of the topic has improved by the way the lesson was taught because it was practical.

Student N- Yes, hands on experience helps me to learn better.

4.4.3 Learning Style:

Some students indicated their learning preference which the 5E Learning cycle provided. Most students indicated that due to the lesson being interactive and because it provided hands-on activities it helped in their learning and understanding. This is supported in statements already stated under the theme engaging learning environment. The lesson also accommodated students who were visual learners and aural learners. This is supported in the following statements:

> Student B- The writing down of the answers to the questions. I rather read it out and say my answer instead.
>
> Student C- …by seeing and experiencing the lesson/topic first hand.
>
> Student K- I only understand most technical things when I actually see it like as practical. So I enjoyed the lesson which was given.
>
> Student K- I think so because it was taught in a visual way I understood.
>
> Student M- …numerous aspects of applying the topic visually, auditorily and written all made it easier to understand.
>
> Student N- …I can actually see what is happening and understand better rather than just hearing about it…

4.4.4 Benefits of Teaching Strategy:

There were also benefits of using this teaching strategy. Some benefits which stood out were *broadening students' perspective, providing a foundation, improving memory, clearing up misunderstandings, arousing interest and instilling focus and autonomy in student learning*. Students showed to indicate taking charge of their own learning as a result of the 5E Learning cycle. Students indicated this by saying:

Student F- We got to do the activities ourselves and come up with the information ourselves…

Student N- …I understood how to figure it out on my own and it was not difficult.

The teaching strategy also seemed to have broaden students' perspective. Students made statements like:

Student B- …I was able to see how much I knew and what others knew and increase my span of knowledge.

Student C- …my peers' more relatable perspective knowledge and understanding would bring me closer to fully understanding the lessons.

Student C-…I enjoyed listening to the different opinions and perspectives of my peers.

Student J- …it added more ideas to my learning from what I had already know.

Student P- …the involvement in class helped me to broaden my thinking about things

Student P- …I would have come across the other things from the input of different students rather than if I did it by myself.

Student P- The class activity…give me a broader understanding of the topic that I may not have had gained had I not done it.

Another benefit of the 5E Learning cycle was clearing up misunderstandings. Students made statements like:

Student F- …the discussion cleared up things I did not understand.

Student G- …the introduction was a bit unclear to me so the class activity help me understand exactly what the introduction was trying to say and the class discussion cleared everything up.

Student L- The class discussions helped in my understanding because it unties the knot meaning things I don't understand at the beginning I understand at the end.

Student M- …after experimenting…and the physical aspects, the two combined assisted in clarifying any misunderstood thought.

The teaching strategy also benefited the students in terms of students being more focused as expressed by Student P "…it helps me to test my brain and reasoning for certain things which also helps me to focus in class and pay attention" and Student G "because I was much more focus". The lessons also were an enjoyable experience for students. Some students made statements such as:

Student A- …being more interactive in class made it fun and interesting this making me want to learn better.

Student D- It was fun to actually be a part and it was educational too.

Student E- …it made the class exciting and made me want to learn more.

Student F- I think the lesson was quite enjoyable…

Student G- I found this experience was quite enjoyable and helpful to my learning.

Student M made a comment that "the concept maps and the introduction helped me to understand by providing a foundation of the concept behind the activity". The teaching strategy also helped improve students' memory. Some made comments like:

Student F- …helped me remember something taught before.

Student F- I think the lesson helped me to remember things I learned on the topic…

Student H- …because I am remembering what I learned.

4.4.5 Non-engaging Learning Environment:

A non-engaging learning environment was another theme identified. Most students compared the way the lessons were taught to ones which were non-engaging. Students made statement like:

Student A- …I learn through hands on activities much better than writing and reading notes.

Student A- …I work better using my hands instead of reading from a textbook.

Student D- When I am being taught and I am sitting down, I would normally feel tired/sleepy so I wouldn't be in a learning mood.

Student K- I honestly might not have understood it by just writing notes.

Student L- …I learned things quicker by doing it with my hands unlike theory where you write and discuss whereas practical you do and discuss…

Student N- I prefer to be active than just sit and listen.

These statements can be interpreted as students' preference for an engaging learning environment which the 5E Learning cycle provided as oppose to traditional teaching methods, which tend to be more teacher centred, unlike the 5E learning cycle which is more student centred.

4.4.6 Undesirable aspects of Teaching Strategy:

All of these statements made thus far have been positive but students also made comments about the 5E Learning cycle which were categorized as undesirable aspects of this teaching strategy. Some were on the spot questioning, complexity of the topic, loads of information, length of introduction, answering techniques, layout of parts of the lessons and concept maps.

Student P thought that the lessons were not beneficial because "I was put on the spot to think about questions". The student went on to say that "I had to answer in a short space of time". This can be interpreted as the student feeling rushed when called upon to answer questions. The topic was also said to be complex which was "confusing" that Student M claimed "instructions for the process could have been clearer". Student E also mentioned, "I wasn't clear as to what the topic was about" which is also another statement showing the confusion that others may have encountered. Also, Student C made claims where the explanation should have been integrated into the practical rather than it being separate. The student claimed that because of this the experience was not enjoyable.

Despite the fact that this study infused concept mapping into the 5E Learning cycle, when students were asked the guided question which aspect of the lesson did not help in their understanding, the majority identified concept maps as the aspect of the lesson which did not help in their understanding or was helpful in their learning. Students made statements such as:

> Student A- Concept maps take up too much time from the actual topic…
>
> Student B- The concept maps. I was very confused and did not know what was going on.
>
> Student B- The concept maps to me was not as beneficial to me, it made no sense.
>
> Student C-The concept maps did not help in my understanding…restricted me time management wise.
>
> Student D- The concept maps didn't help me at all in my understanding. It made me confused and uninterested in the topic…they seemed quite useless to me.
>
> Student E- The concept map wasn't too helpful or enjoyable because I was clueless as to what to include in it…
>
> Student G-The concept maps did not help my understanding because I did not understand how to make much sense of the concept map.
>
> Student I- The concept maps were no helpful/enjoyable because it took up some of the time we could have use to do other things.
>
> Student L- I didn't really like the part where you had to do a concept map because I sometimes get mix up on how to do it.

From the statements above, the concept maps seemed to be too time consuming for students, which some felt took away from the actual lesson itself as expressed by Student A, C, D and I.

Even though students were exposed to concept maps before the study, students still expressed confusion in their construction and that the maps did not help in their understanding, as seen by Student B, D, E, G and L.

Some students felt that the length of the introduction affected their learning and understanding. Student A stated that "the introduction is really long to be honest. My attention span is very short therefore it was hard for me to pay attention through the entire lesson" while Student C said "I found the introduction helpful but not as efficient… [it] was too brief". Others stated that the introduction was a confusing. Some students made statements like:

> Student G- The introduction was not beneficial because I did not understand the introduction…
>
> Student I- The introduction was not beneficial because I did not understand what was being done.
>
> Student I- The introduction did not help because I was not sure of what was going on until we got into the class activity and discussion.
>
> Student L- the introduction was not really beneficial to my learning because I get lost in what we are doing and I have no idea what is going on.
>
> Student N- The introduction …did not seem useful or beneficial.

4.4.7 Personal feelings towards Science:

A few students expressed their dislike towards science, which seemed to have affected their learning and understanding. Student K and N both stated that they don't really understand or like chemistry. In addition, there were students who did not see the relevance of the unit of work taught, in their daily lives. Student D claimed that "…in my own opinion learning about rusting and reactivity in metals etc. is not relevant to me in life". Student K made similar statement stating that "…in my opinion rusting is unimportant to me".

Chapter 5

Discussion, Implications and Recommendations

5.1 Discussion:

This study investigated the effect of using the 5E Learning cycle on students' conceptual understanding and students' perceptions of how this teaching strategy affects their understanding and its use as a learning tool.

A *t*- test was done for the concept and concept map scores for each lesson. The null hypothesis was rejected for both the concept and concept map scores for the "Physical properties and Bonding" lesson taught, indicating that the 5E Learning cycle had an impact on students' conceptual understanding. The same findings were found for the Displacement II and Rusting lessons. However, the null hypothesis was accepted for the Displacement I and Tarnishing lessons, indicating there were no significant differences in the concepts and concept maps after teaching using the 5E Learning cycle.

On closer analysis of the constructed concept maps some additional findings stood out. In the lesson *'Physical Properties of Metals and Metallic bonding',* electrical and heat conductivity, malleability, state and reflection of light were the physical properties that students identified for metals. While students were able to identify that electrical conductivity was a physical property, they still displayed misconceptions about their understanding of how metals are able to do so. The results also showed that all students were able to correct their misconception that metals exist naturally as solids. There was also a marked improvement in their understanding of the heat conductivity concept. Students displayed a very erroneous view in their PRMS about the type of bonding found in metals. Most students believed that ionic bonding and/or even magnetism was responsible for keeping the particles in a metal together. However, the POMS showed that students were able to rectify this misconception. Also, even though students were able to list malleability as a property, they were not able to explain how this was possible.

Comparing the SCAT and the concept maps, it was seen more students showed an understanding of the type of particles present in metals and salt solutions at the end of the unit. Students still held erroneous views about the mass of the metal oxide formed due to tarnishing and that of rust. Most students maintained the belief that the mass of these products would be less than that of the respective metals. In addition, at the end of the unit, students were able to identify the conditions needed if rusting is to occur. In the concept maps, while students were able to list different methods of rust prevention, they failed to give an explanation for the techniques listed. This manifested itself again at the end of the unit. Most students not only failed to give an explanation for the prevention method but also failed to identify the metal involved in sacrificial protection/galvanizing.

The majority of students were able to identify colour change with chemical reaction at the end of the unit. However, most were unable to explain how the colour change came about. About 9 out of 16 students were able to explain how hydrogen gas is produced in a displacement reaction between and acid and a metal. While under half of the participants correctly identified that a reactive metal produces hydrogen gas in the presence of an acid. Generally, the concept maps and the SCAT show that students still cannot fully explain displacement reactions.

Students' perceptions about the 5E Learning cycle as a learning tool and its use to help in students' understanding were gathered using journals. Findings show that students believed that the 5E learning cycle provided an engaging learning environment which helped in their understanding. This engaging learning environment also appealed to students with different learning styles which students claimed helped in their learning and understanding. Thus, the 5E

Learning cycle was a useful learning tool. Students also felt that in addition to helping with their understanding, other benefits stood out, such as; broadening perspective, providing a foundation, improving memory, clearing up misunderstandings, arousing interest, instilling focus and student autonomy in learning.

Journal entries also mentioned undesirable aspects of the 5E Learning cycle, such as, on the spot questioning, length of introduction and the layout of parts of the lessons. A small number of students felt that science was irrelevant to them, this could have affected their understanding and learning.

5.2 Conclusion:

The results from this study show that students were able to correct some misconceptions at the end of the unit, indicating that conceptual change did occur. Thus, students would have gone through the four stages –dissatisfaction, intelligibility, plausibility and fruitfulness- for this change to occur. However, other misconceptions still remained. Students either showed no change in their views or reverted to their original beliefs at the end of the unit.

According to the students, the 5E Learning cycle provided and engaging environment. Overall, they believed the teaching strategy helped in their understanding and learning. The 5E Learning cycle allowed students to explore and be engaged in the lessons and give explanations for their experiences. This constructivist approach allowed students to derive scientific facts/concepts after engaging in hand-on activities and discussions with their peers and teacher; that students would not have been able to conceive on their own. However, there were some aspects which they believed were undesirable which would have contributed to their learning and understanding. The learning environment allowed students to be engaged in constructing knowledge.

5.3 Implications:

Students existing knowledge were taken into account in preparing the lessons since "lessons should not merely proceed from ignorance to knowledge but should neither have one set of knowledge replace another" (Barke, Hazari, & Yitburek, 2009). Incorporating or designing lessons around misconceptions will provide disequilibrium, thus students will have to reconstruct their knowledge. Thus inquiry process of the constructivist approach will reveal to students some of their own misconceptions. Therefore, proper training of this constructivist approach will help inform practice with the intention to develop students' conceptual understanding.

5.4 Recommendations:

Based on the results, the researcher recommends that:

Similar research studies be conducted to develop students' conceptual understanding using the 5E Learning cycle in the science field.

Also, further studies can be conducted using concept maps to monitor students' conceptual understanding.

And finally, studies can be done where this constructivist approach can be compared to other teaching methods to determine its effectiveness.

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