Effectiveness of Concept Mapping: - A Constructivist based Educational Strategy, on Grade Seven Arab Students' Academic Achievement in Chemistry.

دراسة استقصائية لفاعلية مفهوم الخطط التفصيلية للاستراتيجية التربوية عبر الإستدلال في التحصيل الأكاديمي لمادة الكيمياء لطلاب عرب بالصف السابع

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ABSTRACT

The present study aimed to determine the effects of concept mapping, a constructivist based learning strategy, on academic achievement in chemistry. The participants were 64 grade seven students in a K-12 British curriculum private school in Dubai, the United Arab Emirates. The study employed a quasi-experimental, pre-test, post-test design using an achievement test called CMAT (Chemistry Matter Achievement Test). The experimental group were taught a topic in chemistry with concept mapping strategy for a period of four weeks and the control group were taught the same topic using expository method for the same period of time. The data collected were analyzed using descriptive and inferential statistics. The mean post test score of the experimental group was found to significantly be higher than the mean post test score of the control group. Results showed that concept mapping is an effective strategy for teaching and learning chemistry concepts. The data analysis also revealed that the concept mapping strategy is capable of enhancing learners' mastery of content at higher order levels of cognition. The findings of this study recommended that chemistry educators should use concept mapping strategy as a pedagogical and evaluation tool as it can enhance students' meaningful understanding of chemistry concepts, longer retention of information and academic performance in the subject content.

Keywords- Concept mapping, student achievement, constructivism, cognition, analysis, evaluating, creating.

المستخلص

تهدف هذه الدراسة إلى تحديد فاعلية مفهوم الخطط التفصيلية لإستراتيجية التعلم عبر الإستدلال بغرض تحقيق الإنجازات الأكاديمية في مادة الكيمياء. وشارك في هذه الدراسة 64 طالب بالصف السابع يدرسون المنهج البريطاني K-12 بمدرسة خاصة في دبي بدولة الإمارات العربية المتحدة. وتم في الدراسة استخدام تصميم شبه تجريبي شمل مرحلتين قبل وبعد الاختبار. والاختبار المستخدم هو اختبار إنجاز يسمى سي ام ايه تي - CMAT (إختبار إنجاز في موضوع كيميائي). تلقت مجموعة التجريب حصص دراسية في موضوع كيميائي بالإعتماد على استراتيجية الخطط التفصيلية لمدة أربعة أسابيع، كما تلقت مجموعة القياس حصص في نفس الموضوع وإنما بالإعتماد على الأسلوب التوضيحي ولنفس المدة الزمنية. وتم تحليل البيانات التي تم الحصول عليها بإستخدام منظومات إحصائية وصفية وإستنتاجية. وكان متوسط علامات بعد الاختبار لمجموعة التجريب أعلى بكثير من متوسط علامات مجموعة القياس. وأوضحت النتائج بأن مفهوم الخطط التفصيلية يعتبر إستراتيجية فاعلة في تدريس وتعلم المفاهيم الكيميائية. كما تبين من تحليل البيانات بإن إستراتيجية الخطط التفصيلية تنطوي على إمكانية تعزيز قدرات الدارسين واستيعابهم للمحتوى بمستوى عال من الإدراك. ومن خلال نتائج هذه الدراسة، تم وضع توصيات بضرورة اتباع معلمو مادة الكيمياء لإستراتيجية الخطط التفصيلية باعتبارها أداة تربوية و تقييمية نسبة لأنها تعمل على تعزيز مستوى استيعاب الطلاب للمفاهيم الكيميائية و على إمكانية المحافظة على المعلومات لفترات طويلة فضلاً عن مستوى الأداء الأكاديمي في محتوى المادة.

الكلمات الرئيسة - مفهوم الخطط التفصيلية ، إنجازات الطلاب، الكيمياء، الإستدلال، المستويات العالية، الإدراك، التحليل، التقييم، أسلوب توضيحي.

DEDICATION

I dedicate this dissertation to my parents, V.U. Thomas (Late) and Mary Thomas, who strived to give me the best education they could. Their love, support and prayers have constantly encouraged me to strive for my dreams. To my husband, Sonu Mathew, who has been a constant source of inspiration and whose love is the greatest gift of my life. To my three daughters, Senaara, Eshaara and Nihaara, for their love, understanding and patience through this endeavor.

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Chapter One: Introduction

A paradigm shift in science teaching and learning is significant since educational reform focused on student achievement has become a major global initiative emphasized by organizations like World Bank, UNESCO etc. Creating a society augmented with scientific literacy is believed to be one of the fundamental goals of science education universally (NRC 1996; AAAS 1993; Aikenhead 2005; Krajcik & Czerniak 2007; Kuo *et.al*.2013; Ackay&Ackay 2015). Science education has continued to be a relevant discipline of studies in academia and there has been several reform efforts in the methodology and pedagogy of K12 science education globally. Several reform efforts have been made to develop effective teaching and learning strategies to increase the pace of meaningful science learning globally and concept maps are considered to be one of the effective teaching strategies in science education. Novak (1998) justify that concept mapping help students learn how to learn as it is an effective pedagogical tool that is metacognitive in nature.

Concept maps are graphical tools used to link concepts hierarchically, starting from more general to specific, by using propositional statements and connected label lines dictate interrelationships among concepts (Novak 1987). Several studies have indicated that meaningful learning of scientific concepts can be enhanced by concept mapping, an effective constructivist teaching learning strategy which has its orientation under David Ausubel's assimilation theory of cognitive learning (Novak & Gowin 1984; Novak 1998; Novak 1990; Novak 2010; Correia 2012; Correia & Cicuto 2014; Jack 2013; Novak & Cañas 2008). Ausubel's assimilation theory of cognitive learning (1968) as cited in Novak (2010), describes meaningful learning as the establishment of non-willing relations towards concepts and when learners choose to relate new information to ideas or link their previous knowledge to new information, meaningful learning is achieved. Novak (2010) summarizes his theory of education as "meaningful learning underlies the constructive integration of thinking, feeling, and acting leading to empowerment for commitment and responsibility". Several studies have proved concept maps as an effective strategy for assessment, curriculum planning and meaningful learning in several discipline of studies that enhances long term retention of information (Novak & Gowin 1984; Ingec 2009; Ambe & Reid-Griffin 2009; Kane & Trochim, 2007). Concurrently, the literature review on the effectiveness of concept mapping on learning indicates a plethora of studies (Horton *et.al*. 1993; Novak 1990; Novak 1998; Nesbit & Adesope 2006; Villalon & Calvo 2011; Novak & Cañas 2008; Correia 2012; Novak 2010; Moon *et.al.* 2011; Karakuyu 2010; Jack 2013; Kinchin 2014).

Experimental research is believed to be the most compelling type of research that can establish cause and effect relationships which directly influences a variable (Fraenkel, Wallen & Hyun 2012, 2015; Slavin 2011) in the field of educational research, as it has been derived from scientific realism. Quasi experimental designs are almost true experimental designs to establish the cause and effect relationships (McMillan & Schumacher 2010; Mertens 2010) between the dependent and independent variables with experimental and control groups, where the researcher controls or manipulates the treatment of participants in groups and measures its effect on each group and have been suggested and adopted by many researchers in the field of educational research (Fraenkel, Wallen & Hyun 2012; McMillan & Schumacher 2010; Mertens 2010). Therefore the study is also focused to provide relevant contributions to the comprehensive work on the effectiveness of concept mapping approach on students' academic achievement by attempting a quasi-experimental research methodology (Cheema & Mirza 2013; Emmanuel 2013; Jack 2013; Soika & Reiska 2014). The current study has been built on several empirical studies, with considerable evidences, that has proved the concept mapping approach as an effective pedagogical and evaluation tool that enhances students' academic achievement in various discipline of studies over other strategies of teaching and learning (Novak 1990; Novak 1998; Nesbit & Adesope 2006; Karakuyu 2010; Villalon & Calvo 2011; Awofala 2011).

1.1 Statement of the Problem

Although science education has gained relevant position in the academia over the few decades, for most students subjects like chemistry needs to be tolerated only upto high school and details to be remebered only for tests. Chemistry is highly conceptual in nature which consists of abstract and complex conceptual relations (Karakuyu 2010; Jack 2013; Boujaoude & Attieh 2008). Due to high conceptual nature, secondary school students' chemistry learning is often characterized by lack of consistency and majority of students engage in rote learning or memorizing the concepts, facts, equations or formulas without making any connections between information, which ultimately leads to fear for learning the subject (Karakuyu 2010; Jack 2013; Ghassan, 2007; Boujaoude & Attieh 2007). OECD (2008) reported that the number of secondary students who pursue higher studies in science has been declined over the years. Chemistry education starts from elementary level as a part of general science and continues all through the high school. Research literature has highlighted crisis in science education due to conventional instructional methods (Yager 1993; Markow & Lonning 1998, Aikenhead 2005; Karakayu 2010; Tytler 2007; Jack 2013). According to Novak (2010), only some learners acquire a deep, meaningful understanding of the information delivered, whereas majority has only a very superficial grasp of the information due to teacher centered approach where misconceptions take place rather than application of scientific knowledge. Cheema and Mirza (2013), in their research study of effect of concept mapping on student achievement, have strongly emphasized the need for a paradigm shift from behaviorism, where students have only a passive role to constructivism, where students construct their own learning to enhance meaningful conceptual learning in science. The urgency to enhance meaningful learning of concepts is evident in all these reform efforts to develop students' interest in various disciplines of science. Therefore, the recommendation is to adopt effective teaching and learning strategies such as concept mapping that prevents rote learning and promote sensible learning as the learner constructs knowledge by linking the concepts, previous knowledge and real life examples and so considered as a constructivist approach (Karakuyu 2010; Jack 2013; Villalon & Calvo 2011; Novak & Gowin 1984; Novak 1990; Novak 1998) and studies prove that this constructivist approach creates positive attitude in students towards the subjects as it actively involves student in constructing learning (Horton *et al*. 1993; Markow & Lonning 1998; Karakuyu 2010) and engage them in learning (Erasmus 2013).

Bouhlila's (2011) study sheds greater light on the quality of education in MENA region by providing the TIMSS, 2007 score data of Mena Region which was below the world average scale. The study indicated lack of cognitive skills as the reason for this poor performance. TIMSS (Trends in International Mathematics and Science Study) 2011 and PIRLS (Progress of International Reading and Literacy Study) 2011 (KHDA 2012) and PISA (Program for International Student Achievement) 2012 (KHDA 2013), score data shows that a significant proportion of students in Dubai are performing below the lowest international benchmarks in reading, mathematics and science. These international assessments examined students on content as well as cognitive domains and the analysis of students' achievement data indicated that students in Dubai are relatively weaker in both the applying and reasoning domain. The underperformance of Emirati students compared to expatriate students have raised concerns about the lack of their cognitive skills across different subjects (KHDA 2012; 2013). The findings highlighted the factors that influence students' achievement, which includes meaningful teaching and learning strategies in which students have an active role in constructing their own learning. KHDA (2012) highlights the relevance of equipping students with a range of cognitive skills such as application, reasoning, analyzing, synthesizing etc. across different discipline of studies.

It is expected that science learning through student-centered instructional strategies should foster inquiry skills, reasoning, problem solving, conceptualizing and communicating skills of students that will enable them to construct their own learning by applying these skills which consequently enhances their confidence and positive attitude towards the subject (Awofala 2011). Concept mapping is a student centered, inquiry based, metacognitive learning strategy that organizes learning and measure students' knowledge structure and organization in higher order levels of cognitive domain (Awofala 2011; Karakuyu 2010; Villalon & Calvo 2011; Soika & Reiska 2014) and can also develop a positive attitude in students toward the subjects (Karakuyu 2010).

The problem under investigation is to determine how the use of concept mapping as an instructional strategy can enhance students' meaningful understanding of some concepts in chemistry and increase students' academic achievement in chemistry with respect to higher order levels of cognition.

1.2 **Rationale and Significance of the study**.

According to Vanides *et.al*. (2005), it is challenging for a science educator to create an exciting, inspiring and inquisitive learning environment that engages all students at the middle school level. They also indicate that monitoring the progress of each student in science and ensuring that they understand all the taught scientific concepts is significant. These challenges make the science teaching at the middle school level demanding and rewarding for science educators. Teaching and learning chemistry is difficult as it involves highly complex conceptual relations which includes concepts which are unfamiliar and abstract in nature (Ghassan 2007; Aderogba & Olarundare 2009; Emmanuel 2013; Meerah *et.al*. 2013; Burrows & Mooring 2015). The best way of improving students' performance in chemistry is to exploit effective teaching and learning strategies which are constructivist or metacognitive in nature that prevents rote learning and enhance meaningful learning. Several researchers point out that concept maps are effective instructional tools that enhance meaningful learning by inculcating thinking skills, creative thinking, motivating learning, enhances knowledge transfer performance etc. (Krajcik & Czerniak 2007; Meerah *et.al.* 2013; Tseng *et. al*.2012; Kostova & Radoynovska 2010; Novak 2010; Novak & Gowin 1984; Burrows & Mooring 2015). A comprehensive review of research proved that concept mapping as an instructional tool, is an effective strategy in enhancing meaningful learning in science, though very few recent studies in chemistry (Karakuyu, 2010; Boujaoude & Attieh 2008; Meerah *et.al.* 2013; Jack 2013; Burrows & Mooring 2015), especially very few (Buldu & Buldu 2010) within UAE or Dubai at the middle school level with students who are native Arabic speakers.

The current study is quite relevant and appropriate in Dubai considering the significant proportion of Students' persistent poor performance in international standardized assessments like TIMSS, PIRLS or PISA (KHDA 2012, 2013), which indicates that students in Dubai are performing below the lowest international benchmarks especially in the cognitive domains such as application and reasoning domains in science. The achievement pattern in students in private and public MoE (Ministry of Education) curriculum schools shows that achievement was lowest in chemistry compared to other content domains in science (KHDA, 2013). The report has raised concerns about the lack of application and reasoning skills in students in science, especially the Emirati students who underperformed in these assessments compared to their expatriate peers across different subjects. The reason for poor performance has been blamed upon the ineffective and improper teaching strategies (Jack 2013) and lack of cognitive skills or understanding of concepts (KHDA 2012). KHDA's (2012) report on TIMSS and PIRLS achievement and KHDA (2013) school inspection handbook states the importance of equipping students with a range of cognitive skills which is directly linked to students' attainment and progress in science. The UAE Vision 2021 National agenda emphasizes on the need of a complete transformation of the current education system and teaching methods and has set as a target that students in UAE rank among the top 15 in TIMSS and top 20 in PISA exams by 2021. According to PISA 2015 draft science framework (OECD 2013), scientific literacy is defined by the three scientific competencies such as ability to "explain phenomenon scientifically, evaluate and design scientific enquiry and interpret data and evidence scientifically" which needs content, procedural and epistemic knowledge. A key new feature of the PISA science draft framework for the year 2015 was defining different levels of cognition within the assessment of scientific literacy, across the three competencies mentioned above (OECD 2013).

The demand for development in the UAE education system calls for a paradigm shift in learning and teaching science. Several studies emphasis on the use of metacognitive strategies in learning and assessment in the higher education institutions in UAE (Forawi, Almekhlafi & Al-Mekhlafy 2011; Tubaishat, Lansari & Al-Rawi 2009). Metacognition can empower meaningful learning (Collins 2011; Veenman 2012; Anderson & Krathwohl 2001) and the metacognitive skills can be enhanced by cognitive visualizations (Villalon & Calvo 2011). A review of studies (Nesbit and Adesope 2006; Karakuyu 2010; Jack 2013; Villalon & Calvo 2011; Novak & Gowin 1984; Novak 1990; Novak 1998; Meerah *et.al*. 2013; Tseng *et.al*. 2012; Kotova & Radoynovska 2010; Emmanuel 2013; Burrows & Mooring 2015) maintain the effectiveness of concept mapping strategy with extensive evidence and justify that concept maps are highly effective cognitive visualization technique and engage students in higher cognitive functions, creates a concrete understanding of concepts and their relationships (Novak 1998; Novak & Cañas 2008; Jack 2013), promote active and meaningful learning rather than memorization (Correia 2012; Erasmus 2013; Burrows & Mooring 2015). The concept mapping strategy can be used to determine the nature of existing ideas of students, make evident the new concepts to be learned, and suggest links between the two which can make learning and teaching effective. The current study is significant as it has confirmed the importance of concept mapping in enhancing meaningful learning by metacognition and constructivism, increasing student achievement by improving cognitive skills, mainly at the higher order levels of cognition and above all develop a genuine interest for science and related disciplines like chemistry right from the elementary and middle school level. The current study's findings can provide relevant contributions to the field of education to understand the effectiveness of concept mapping when used as an instructional strategy to enhance meaningful learning of difficult concepts and therefore increase the academic achievement of students and develop a positive attitude towards chemistry, especially the native Arabic speakers who receive education in the medium of English. It is hoped that the current study will fill the gaps between the theories of constructivism and metacognition and its application on learning and academic achievement of students in chemistry.

1.3 Purpose and Questions of the Study

The purpose of this study is to investigate the use of concept mapping as an instructional strategy in enhancing students' achievement and meaningful understanding of difficult chemistry concepts at the middle school level. The study also attempts to determine whether the use of concept mapping strategy would affect students' higher order levels of cognition such as analysing, evaluating and creating levels of the domain. The study was mainly built on several empirical studies on effectiveness of concept mapping approach on wide range of disciplines within diverse contexts and a range of variables and was guided to some extent by the revised bloom's taxonomy of educational objectives in designing the instrument (Anderson & Krathwohl 2001). According to OECD's (2013), science draft framework for PISA 2015, "Bloom's revised taxonomy identifies factual, conceptual, procedural and metacognitive domains of cognition level heirarchially and allows lower levels of knowledge to be crossed with higher order skills". It has been assumed that to enhance meaningful learning of difficult concepts, effective teaching and learning strategies based on constructivist and metacognitive theories should be used. A quasi-experimental method to determine the cause and effect relationship between variables assigned for an experimental group and control group using a pre-test post-test design on a selected topic of chemistry, considered to be the appropriate method for this investigation. The researcher being the participants' general science teacher and her knowledge about the learners' learning needs supported in designing lesson transcripts, learning resources and the CMAT (Chemistry Matter Achievement Test).

1.3.1 Research Questions and Hypotheses

The current study addresses the following questions,

1. To what extent does the concept mapping strategy affect students' academic achievement in chemistry?
2. To what extent does concept mapping strategy affects the students' achievement

scores in higher order cognitive objectives such as analysing, evaluating and creating levels of chemistry instruction?

Hypotheses formulated for the study are as follows:

1. There would be significant difference in the achievement scores of students taught by concept mapping approach than that of those taught by the lecture method.
2. There would be significant differences in the students' achievement scores in analysing, evaluating and creating levels of cognition after being taught by concept mapping strategy than by conventional method.

1.3.2 Methodology in Brief

The study was a four weeks investigation which was carried out in a K-12 British IGCSE curriculum School in Dubai, the UAE. The participants were from two classes of grade seven (7), consisted of sixty four (64) native Arabic speaking students, which includes thirty one (31) males and thirty three (33) females within an age range of 11 to 12. A quasi experimental research design is employed in the study. A non-equivalent group pretest-posttest experimental design with maximum naturally occurring comparisons as possible is considered (Fraenkel, Wallen & Hyun 2012, 2015, p.271). A pre-test consist of questions to examine the cognitive skills like remembering, understanding, applying, analysing, evaluating and creating was done on the topic taught. Thirty one (31) students (15 males and 16 females) were assigned as the experimental group, who were taught the topic by using concept mapping approach and thirty three (33) students (16 males and 17 females) were assigned as the control group who received the conventional method of teaching. The researcher being a science teacher of the participants had taught a topic of chemistry to both the experimental and control groups for four weeks, meeting five times a week. The same questions of pre-test was given as a post-test to measure and compare the effectiveness of concept mapping approach on the academic achievement of students.

1.4 Structure of Dissertation

Chapter 1 presents the background of the study, statement of the problem, significance, rationale of the study, objectives of the study, research questions, hypotheses and brief description of methodology. Chapter 2 outlines the definition of terms, a comprehensive theoretical overview of related topics such as Ausubel's Assimilation Theory of Meaningful Learning- A psychological Foundation, Epistemological constructivist and metacognitive nature of concept maps, instructional implications of Ausubel's assimilation theory, basic principles of concept maps which include construction of concept maps and different types of concept maps followed by review of extensive related studies. Chapter three outlines the methodology of the research which includes context of the study, participants and site, research design used, instrumentation, pilot study and ethical considerations. Chapter four sketches the analysis of data and findings. Chapter five summarizes the discussion, conclusion, implications and recommendations.

Chapter Two: Literature Review

Introduction

One of the major goals of science education all over the world is to develop scientific literacy in students. Science Council of Canada, based on several educational reforms in USA, as cited in Monkman (2001) asserts that science prepares students for extensive work opportunities of the world by enhancing students' personal development and the learners cognizant participation in a technological society, which is a part of a continuos processing in education. Several researchers further support Monkman and have categorized the basic objectives of science education into scientific inquiry and knowledge, issues of the society, personal needs as well as career awareness (Yager 1993; Kolstoe 2001; Krajcik & Czerniak 2007; Trowbridge, Bybee & Powell 2000; Ackay & Ackay 2015; Donnelly 2010; Kuo *et. al.* 2013). NRC (1996) cited in Krajcik and Czerniak (2007) has emphasized the relevance of studying science that science is an essential subject especially in the elementary and middle school level as students develop interest in science and understanding about the world at this level, which consequently leads to pursue advanced scientific studies.

According to Akpan (2006) as cited in Emmanuel (2013), "chemistry is the study of matter and the changes that matter undergoes". Chemistry is regarded as an experimental science which involves the study of many theories with abstract concepts such as, mole, atomic structure, reaction rate, Chemical equilibrium etc. and students find difficulty in comprehending these concepts (Emmanuel 2013). He further points out that many different strategies like use of models, posters, simulations to explain the abstract concepts have not been fostered meaningful learning of these abstract concepts.

Teaching is effective only if the teaching strategies used are effective for the learner to achieve the desired learning objective and improve student achievement. Concept mapping has been effectively promoted in literature as an effective instructional strategy to enhance meaningful learning of abstract concepts and in assisting learning regarding changes in concepts (Novak 1990). According to Jack (2013), concept mapping approach is currently gaining much popularity in science education as it is considered as a reliable instructional tool used by teachers to assess students' understanding, by students to enhance meaningful learning and by experts as a means of communicating their ideas and knowledge. It is effective in the field of science education to enhance students' understanding of concepts and relationships within domains of science (Jack 2013). Several studies have proved the use of concept mapping as an effective strategy in enhancing meaningful learning in science, though very few recent studies in chemistry (Emmanuel 2013; Boujaoude & Attieh 2008; Meerah *et.al*. 2013; Jack 2013; Burrows & Mooring 2015). Thus it is imperative to suggest concept mapping as an effective strategy to be used by science educators to enhance meaningful learning in difficult concepts in chemistry that would result in improved student achievement rather than memorizing concepts.

Concept maps were established in 1972 in the progression of research study on changes in children's knowledge of science by Novak at Cornell University (Novak & Cañas 2007). They have introduced concept mapping as a strategy to represent and share knowledge. The study was based on David Ausubel's theory of meaningful learning by assimilation of new concepts linking to existing concepts retained by the learner which is referred as the learner's cognitive structure (Novak & Gowin 1984). Cognitive structure is associated with the kind and amount of the knowledge possessed by an individual and how well it is organized in mind.

2.1 Concept Mapping- Definition and Features

According to Novak and Gowin (1984) concept mapping is a way to assess the structure and organization of a learner's existing knowledge and his ability to connect this existing knowledge to new information. Concept mapping is a "technique used to represent the relationships among concepts in a two dimensional graph" (Liu & Hinchey 1996, p. 921). According to Jonassen, Beissner and Yacci as cited in Awofala (2011) concept maps are used to represent the knowledge structures that are already stored in human mind by spatial relationships and interrelationships of concepts. Concept maps are instructional metacognitive instrument designed to assist students learn how to learn (Novak 1998) in which concepts are sequenced hierarchically, starting from more general to specific, by using propositional statements and connected label lines that dictate the interrelationships among the concepts (Novak 1987). They are graphical representations used to organize and represent an individual's knowledge and show relationship among concepts (Novak & Gowin 1984). Concept maps are visual graphic organizers which are cognitive in nature, that make use of information, lines, arrows, and spatial alignments to demonstrate how content ideas and concepts are structured and related (Guastello, Beasley & Sinatra 2000).

According to Novak and Gowin 1984, concept maps are effective because they let students structure and organize their understanding of knowledge. Concepts maps are designed to enhance learners' understanding of concepts by expressing concepts and propositions known to the student and making them visually ostensible to enable their relationship with newly learnt concepts (Jack 2013). Concept maps are based on visual imagery and are easily comprehended than the words that represent an abstract information (Terry 2003). One significance of concept map is that the prior knowledge which has qualitatively and quantitatively different knowledge structures is visible in it (Hay, Kinchin & Lygo-Baker 2008; Popuva-Gonci & Lamb 2012) and this is further linked to new ideas. According to Guastello, Beasley & Sinatra (2000), concept mapping can be used to translate ideas from texts into graphic representations that exhibit whole relationships, by creating a network of content ideas. Davies (2011) pointed out that the main benefit of concept mapping is its relational aim as it allows relational linking between the concepts.

2.1.1 Construction of concept maps

The first development of concept maps was pioneered by Novak and Gowin (1984) based on Ausubel's assimilation theory of learning in which a focal concept is used along with several key concepts (Chularut & Oklahoma 2001). According to Novak and Gowin (1984), the steps of constructing a concept map are as follows:

- Read the material thoroughly and identify the concepts to be mapped.
- Select the focal concept and other key concepts and group them based on their interrelationships. A good focal question helps to keep our thoughts focused on the key concepts to be mapped and also a relevant parameter to select important concepts and linking phrases to make the network (Correia 2012).
- Arrange the focal concepts and other clustered key concepts and link those using lines or drawing arrows from the most abstract to the most specific and include relevant examples at the lowest point of the hierarchical representation.
- Label the connecting lines between the concepts to represent meaningful relationships between the concepts. The use of linking phrases to elucidate relationships between concepts make concept maps powerful than other graphical organizers (Davies 2011).
- The maps can be redesigned or modified as more knowledge is gained by research.

  Kiliç and Çakmak (2013) further support the steps of concept map construction in their study of using concept maps as a tool for meaningful learning and teaching in chemistry education.

  Figure 2.1 shows a list of concepts to address a focal question, What is a Plant?, and a simple Novakian concept map which incorporates the concepts into a network of meaningful learning material by representing the relationships between the concepts with connecting lines and linking phrases (Novak 1998).

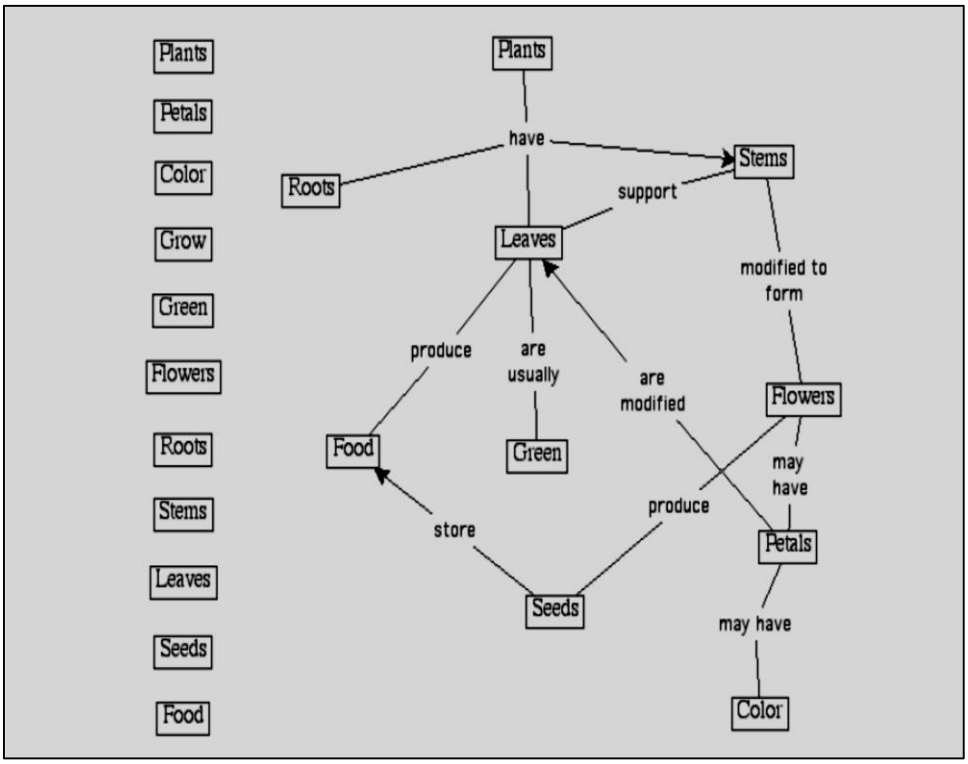

Figure 2.1. A Simple Novakian Concept Map

2.1.2 Types of Concept Maps

The logical structure of the abstract concepts determines the configuration of the concept map (Harris & Zha 2013). There are five kinds of concept maps according to the University of Illinois as cited in Kiliç & Çakmak (2013). Awofala (2011) called concepts maps semantic networks as the knowledge is presented semantically. Several researchers indicate the following different kinds of concept maps briefly in their literature (Harris & Zha 2013; Awofala 2011; Kiliç & Çakmak 2013).

(1) Spider Concept Map

A spider concept map is a kind of graphical representation that is used to enumerate various aspects of a single theme or topic. The main topic will be at the centre of the spider concept map which will be surrounded by the sub topics as indicated in figure 2.2. Spider concept map helps students to organize their thoughts. As the name indicates it looks like a spider's web.

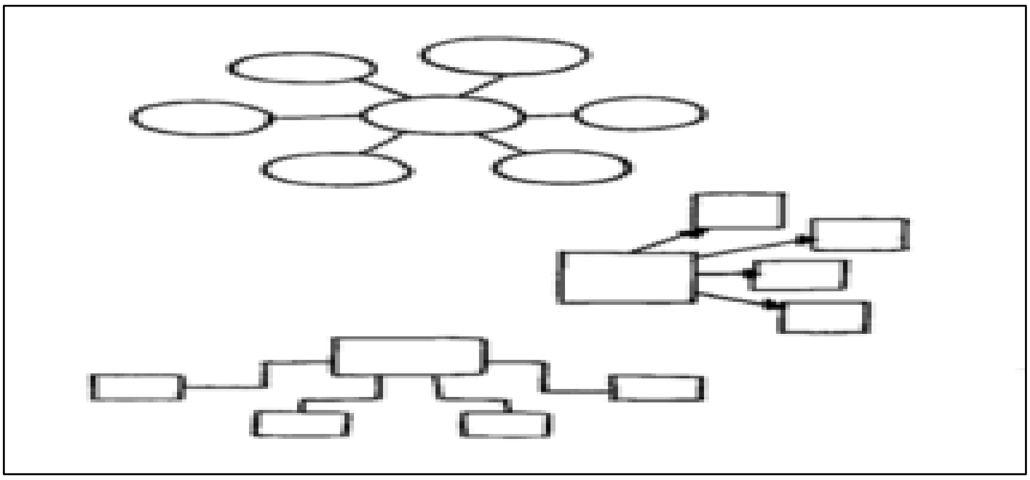

Figure 2.2. Spider Concept Map (https://cct370-w07.wikispaces.com/Cmap)

An example of a spider concept map with a chemistry content is shown in figure 2.3.

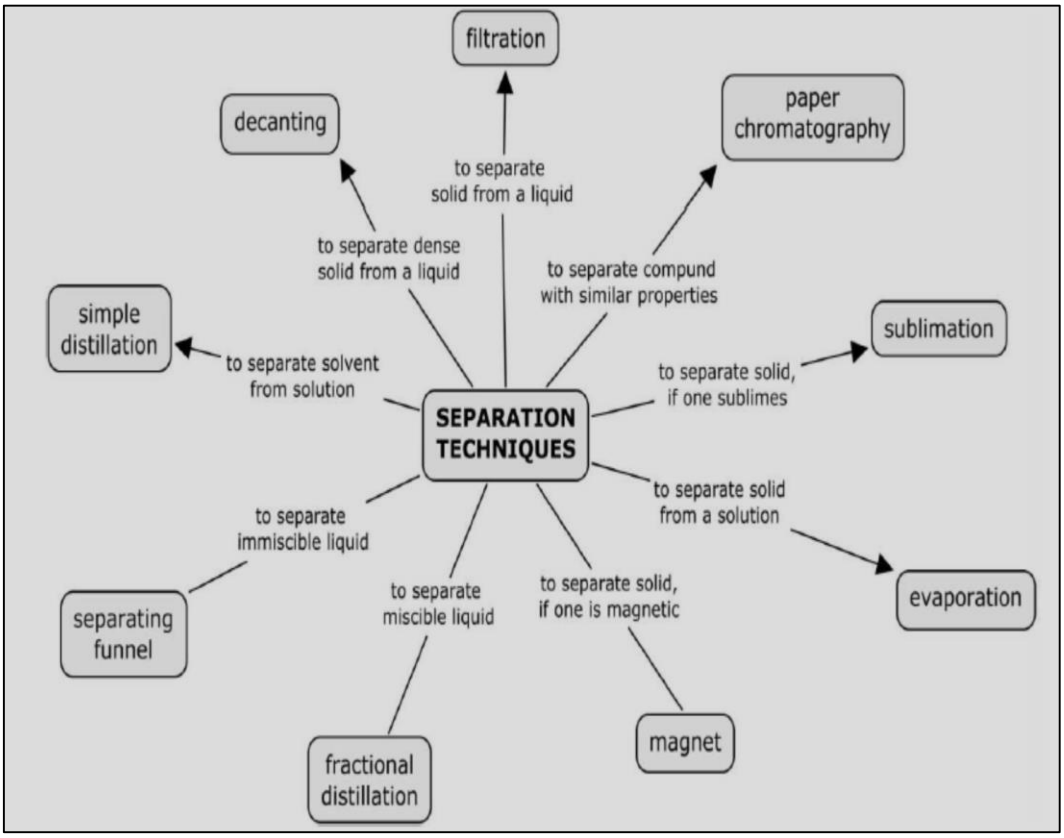

Figure 2.3. An example of spider concept map with a science content (Kiliç & Çakmak 2013)

Spider concept maps are easy to construct and read as all data is gathered around a unified theme. However, this kind of concept maps do not allow for the integration of all data and relationships among data and do not foster critical thinking (Harris & Zha 2013; Kiliç & Çakmak 2013).

(2) Hierarchical/ Chronological Concept Map

The hierarchical or chronological concept maps follow a definite pattern that presents information in descending order of relevance. They are easy to read. The most important data is located at the top and moves down to the most specific. It helps to understand and correlate the concepts. However, they lack depicting relationships usually and thus facilitate only limited critical thinking in learning (Harris & Zha 2013) Figure 2.4 represents the hierarchical concept map.

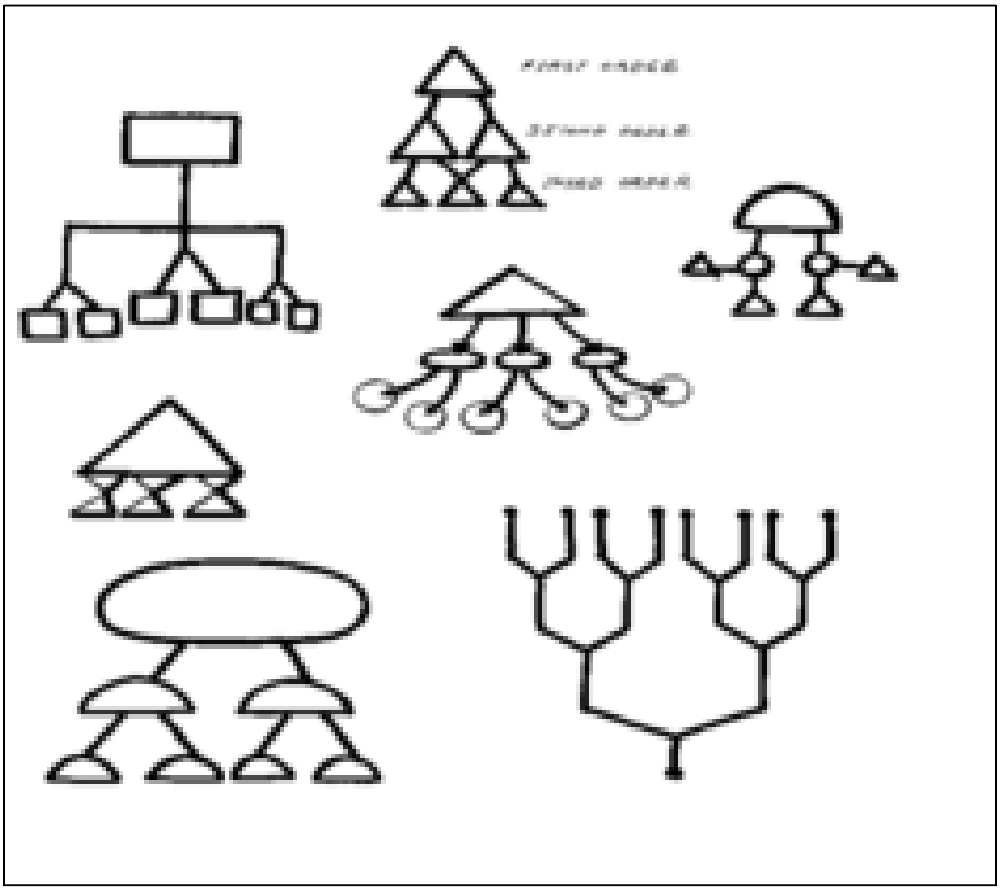

Figure 2.4. Hierarchical or Chronological Concept Map

(https://cct370-w07.wikispaces.com/Cmap)

An example of hierarchical concept map with a chemistry content is shown in figure 2.5 as cited in Kiliç & Çakmak (2013).

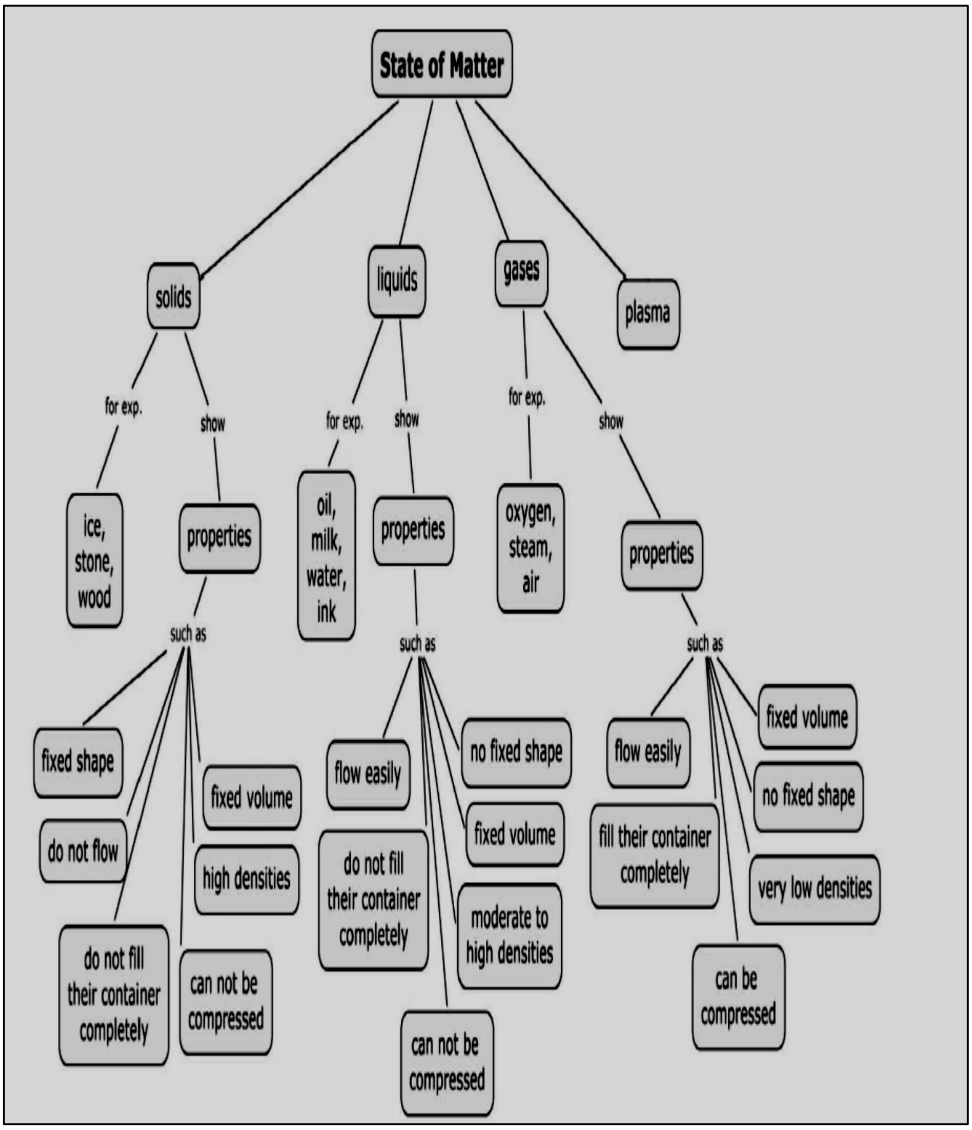

Figure 2.5. Hierarchical Concept Map about States of Matter

(3) Flow Chart Concept Map

The flow chart concept map organizes information in a linear format. Information is organized in a logical, ordered manner. A diagrammatic representation of flow chart concept map is shown in figure 2.6. They have the similar advantages and disadvantages as the spider concept maps.

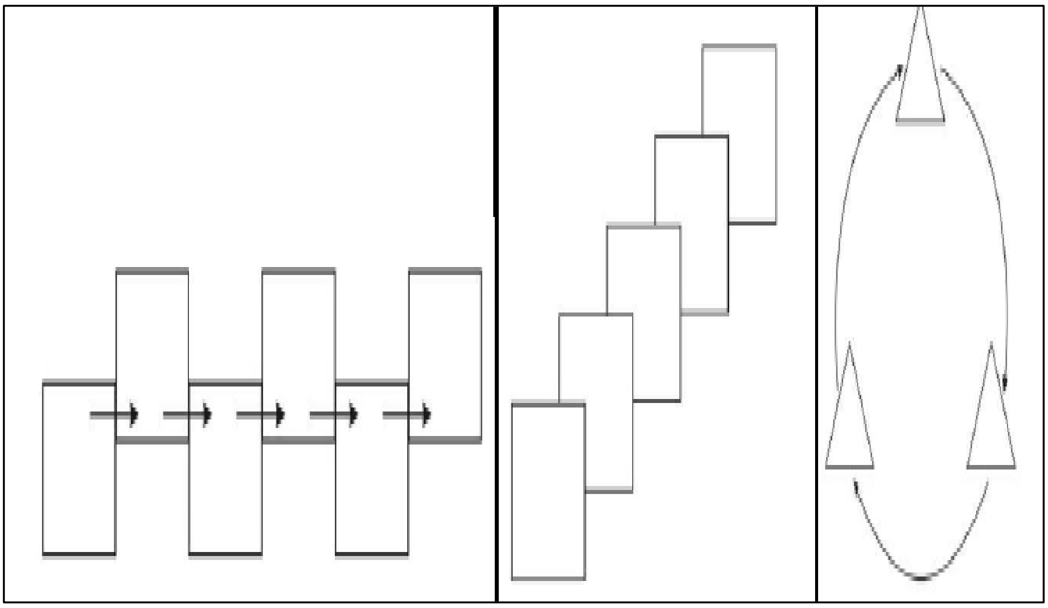

Figure 2.6 Flow Chart Concept Maps (Kiliç & Çakmak 2013)

An example of a flow chart concept map on scientific method is shown below in figure 2.7

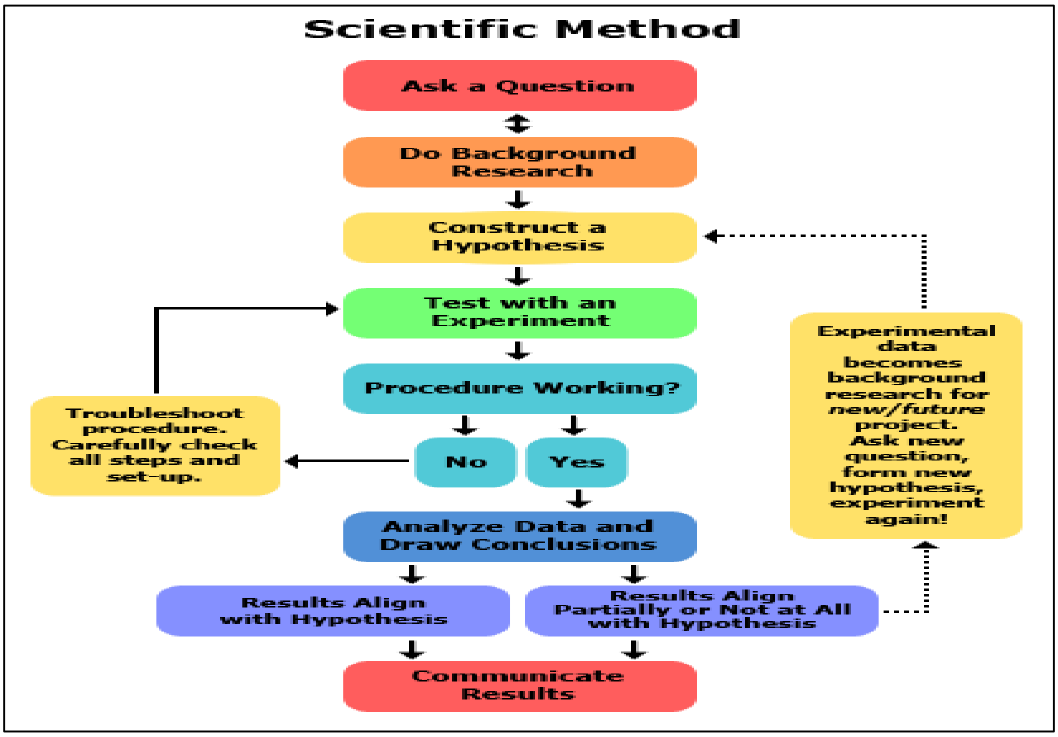

Figure 2.7 – Flow chart concept map about Scientific Method

(www.ScienceBuddies.org)

(4) Systems Concept Map

The systems concept map structures information similar to a flow chart by adding INPUTS and OUTPUTS which includes all data and shows many relationships between data. According to Harry and Zha (2013), system concept maps represent all the aspects of an abstract concept symbolically by relating the concepts in the content and linking them to theory and application. Kiliç & Çakmak (2013) and Harris and Zha (2013) claim that this kind of concept maps facilitate critical thinking and problem solving skills. Figure 2.7 gives a diagrammatic representation of systems concept map.

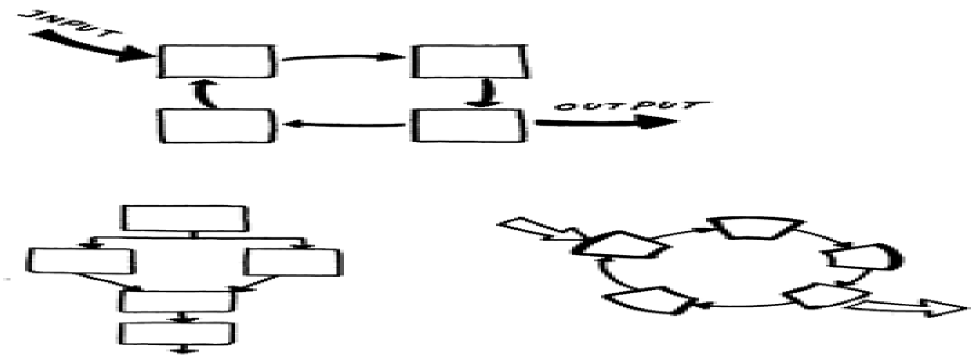

Figure 2.8 Systems Concept Map (Kiliç & Çakmak 2013)

The concept of photosynthesis and cellular respiration is represented in the form a system concept map as shown in figure 2.9 as cited in Kiliç & Çakmak (2013).

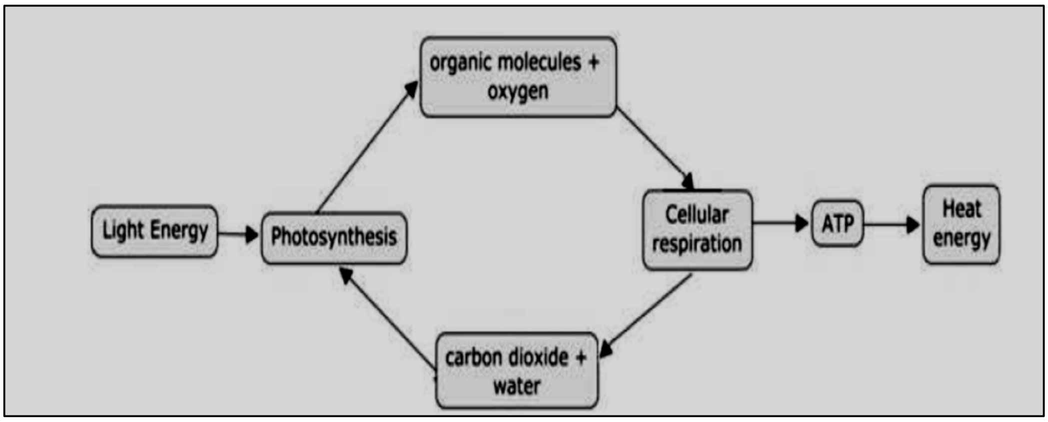

Figure 2.9 Systems Concept Map about Pollution and Cellular Respiration

(5) Multi-dimensional Flow Concept Map

Multi-dimensional concept maps are used to describe the representation of data which is difficult to represent in a two dimensional concept map. Figure 2.10 gives a diagrammatic representation of multi-dimensional concept map

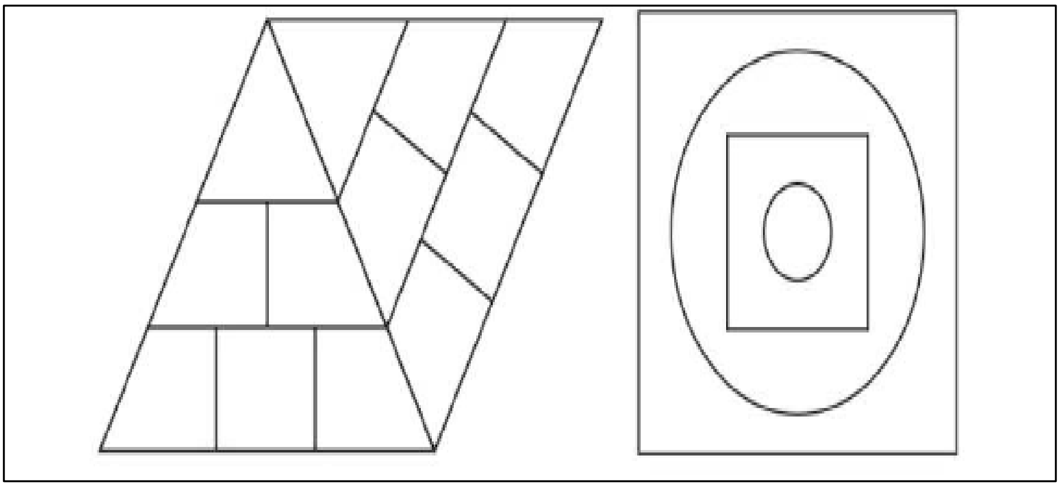

Figure 2.10 Multi-dimensional Concept Map (Kiliç & Çakmak 2013)

An example of a multidimensional concept map of a chemistry topic is given in figure 2.11 (Kiliç & Çakmak 2013)

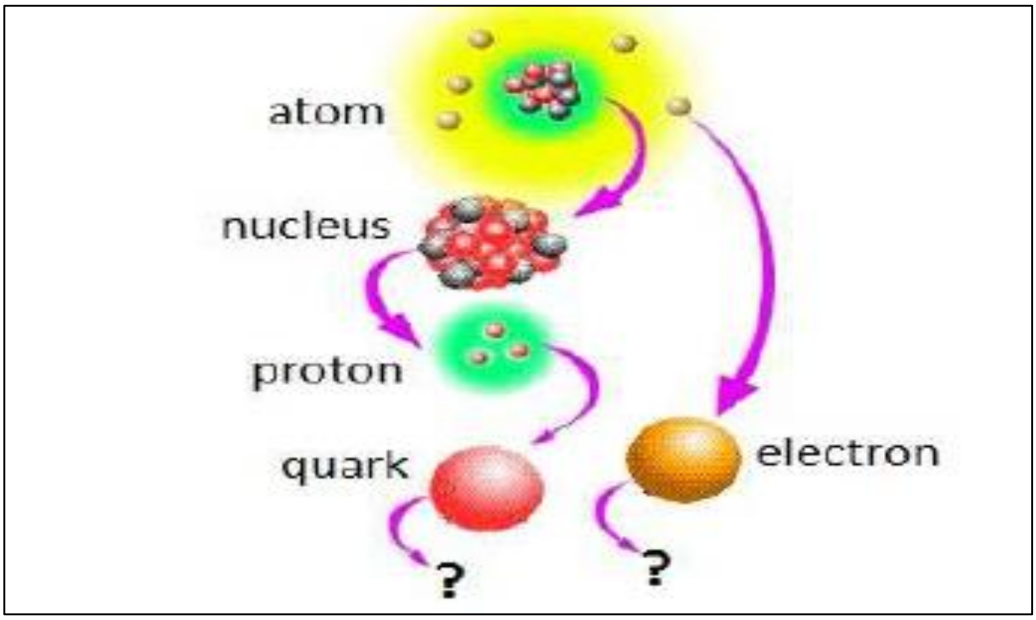

Figure 2.11 Multidimensional concept map about atom (Kiliç & Çakmak 2013)

2.2 Theoretical Foundations

Literature review reveals psychological and epistemological foundations for the development of concept maps (Novak 1990; Novak & Gowin 1984; Novak & Cañas 2007; Novak 2010)

2.2.1 Ausubel's Assimilation Theory of Meaningful Learning: A Psychological Foundation

David Ausubel is one of the educational psychologists who made relevant contributions to the field of education which include his assimilation theory of meaningful learning. Ausubel's assimilation theory of meaningful learning was published in 1963 and mainly provides psychological foundations of concept maps. The pivotal concept of his learning theory is the concept of meaningful learning (Ausubel *et.al*. 1978). The main idea of his theory is the distinction between the surface learning and meaningful learning which deals with three concerns such as curriculum content, learning and instructions. According to Ausubel, "meaningful learning requires three conditions: (1) the material to be learned must be conceptually clear and presented with language and examples relatable to the learner's previous knowledge. (2) The learner must possess relevant prior knowledge. (3) The learner must choose to learn meaningfully" (Novak & Cañas 2007, p.30). In his view students must relate new knowledge to their existing knowledge to learn meaningfully. Ausubel (1963) and Ausubel *et.al.* (1978) claims that new concepts to be learned can be incorporated into graphic representations of concepts. He further emphasizes on teacher's role for organizing and presenting concepts to be learned to enhance meaningful learning and for motivating students to choose to learn meaningfully by incorporating new ideas into existing ones rather than rote learning the concepts (Novak & Gowin 1984; Novak 1990; Novak 2010; Otor 2011). Ausubel's theory is focused on strengthening learner's existing cognitive structure which is a relevant factor in assimilating new ideas and this facilitates their acquisition and retention of new information. The theory supports that there is an affective commitment to relate new knowledge to prior learning where as in rote learning there is no affective commitment. The meaningfully acquired knowledge is retained for a longer time and is used to solve problems in new situations to facilitate further meaningful learning (Novak 2010).

2.2.2 Instructional Implications of Ausubel's Assimilation Theory

Ausubel's assimilation theory of meaningful learning which involves the subject, learner and cognitive structures has relevant implications on the organization of content and instructional procedures. His theory consists of a number of processes, namely, subsumption, progressive differentiation, obliterative subsumption, superordinate learning, and integrative reconciliation (Ausubel *et.al.*1978). Ausubel uses progressive differentiation and integrative reconciliation to guide the organization of the content in such a way to enhance meaningful learning of concepts in the subject fields in which the learner retains the information for a longer time. Progressive differentiation means that the ideas are presented from most general to detail and specificity in which the concepts become more elaborated and differentiated and integrative reconciliation means the process of reconciling new ideas linked to previously learned concepts even if the details are lost, which is a very relevant process in science learning as it is building up of concepts (Ausubel *et.al.* 1978; Chularut & Oklahoma 2001; Nesbit & Adesope 2006). This supports his claim that if progressive differentiation of concepts are provided, then integrative reconciliation follows naturally with active cooperation of learner. Ausubel (1978) asserts that advance organizers are effective instructional tools to strengthen cognitive structure and enhance meaningful learning. Based on his ideas of assimilation theory of meaningful learning, different strategies for learning concepts in science have been developed. Novak and Gowin (1984) have developed an instructional theory incorporating concept maps that graphically represents new concepts linked to previous knowledge. Novak (2010, p.23) claimed that if thinking, feeling and acting is constructively incorporated that enhances meaningful learning, can empower learners to be committed and responsible. The theory of meaningful learning emphasis on transforming information to long term memory from short term memory when students learn complex ideas from their own experience and linking new information to prior knowledge.

2.2.3 Epistemological Foundations - Constructivist and Metacognitive Nature of Concept Maps

“Epistemology is the branch of philosophy that deals with the nature of knowledge and new knowledge creation” (Novak & Cañas 2007, p.33). Novak (1987; 1993) as cited in (Novak 2010) explains a close relationship between constructivist epistemology (Kuhn 1962) and Ausubel’s theory of human learning. Novak describes this as human constructivism in his refined theory of education (Novak 2010). Learners learn through concept maps create new knowledge and create new meanings (Novak & Cañas 2007; Novak 2010). Novak & Cañas (2007) assert that concept maps facilitate meaningful learning and new knowledge creation which has constructivist epistemology has its foundation in which knowledge is a human construction from which new ideas are evolved (Novak 1987). A conceptual overview of Novakian concept map is represented in figure 2.12 which explains concept maps.

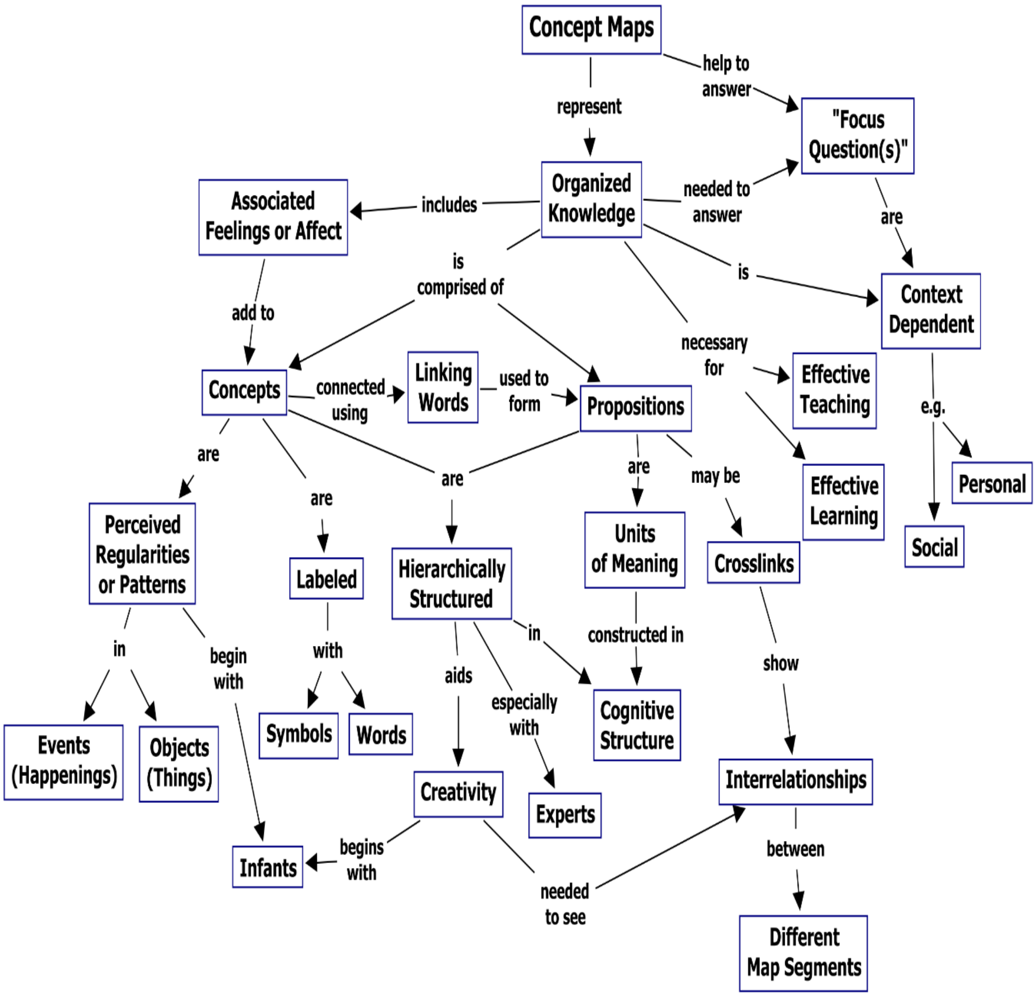

Figure 2.12. A Conceptual Overview of Concept Maps (Novak & Cañas 2006).

The constructivist approaches of learning emphasizes on interaction between learner and learning environment and during this interaction prior knowledge is used to interpret and construct new ideas. Concept map is a metacognitive strategy that uses affective as well as cognitive skills to enhance pattern recognition and stimulate meaningful learning (Irvine 1995; Novak & Gowin 1984) and to promote critical thinking skills (Ku & Ho 2010).

Several studies have proved the relevance of metacognition and use of concept maps as effective metacognitive tools to facilitate meaningful learning (Novak & Cañas 2007; Lai 2011; Collins 2011; Veenman 2012). According to Veenman (2012, p.27), "metacognitive self-instructions and the cognitive processes that are involved in the execution of those instructions" are integral parts of cognitive systems. Villalon & Calvo (2011) claim that the cognitive visualization technique such as concept mapping can facilitate the development of metacognitive skills. Metacognition is the process of developing self-awareness and ability to self-assess one's own process of learning (Ku & Ho 2010). Villalon and Calvo's (2011) study further extend evidences that drawing a concept map requires students to engage in higher cognitive functions. Correia (2012) emphasized on the use of concept maps to promote meaningful learning rather than surface learning. Correia (2012) also points out the relevance of concept maps in supporting collaborative construction of knowledge which improves communication and thus meet the demands of our contemporary society for strategic knowledge management. According to Novak and Cañas (2008) the hierarchical structure and the ability to search for and characterize new cross-links are the important features of concept maps that facilitate creative thinking. Villalon and Calvo (2011) further supports the relevance of concept maps in enhancing a person's understanding of a topic by mapping concepts and their relationships represented in a hierarchical structure. Jack (2013, p.10) pointed out that concept mapping can make learning an active process by enhancing a meaningful and precise understanding of the meaning of concepts and their interrelationships.

2.3 Concept mapping as an Instructional Strategy– Related Studies

Joseph Novak and the members of his research group introduced concept maps as a graphical tool to evaluate children's understanding of science by organizing information (Novak & Gowin 1984; Novak 2010; Novak & Cañas 2007). Concept maps have been extensively used and verified as pedagogical tools since its inception (Novak Cañas 2007). Meaningful Learning: The Essential Factor for Conceptual Change in Limited or Inappropriate Propositional Hierarchies (LIPHs) Leading to Empowerment of Learners (Novak 1993) is an excellent article by Joseph Novak which explains the structural theory and design of the concept map.

2.3.1 Concept Mapping as a Pedagogical and Evaluation Tool

The concept mapping strategy has been adequately advocated in literature as effective tools to facilitate meaningful learning of abstract concepts (Novak 1990), as a way of graphical representation of frameworks for the relationship between concepts (Novak & Gowin 1984; Stewart *et.al*.1979) as a teaching and assessment tool to foster purposeful learning (Liu & Hinchey 1996). To sum up, concept maps are used as means for meaningful learning and knowledge construction, instructional planning and curriculum development, assessment and evaluation, identifying understanding and misconceptions of key ideas and helping them achieving correct conceptual learning (Novak 1990; Mintzes *et.al*. 1997; Nesbit & Adesope 2006; Novak & Cañas 2007; Ikeobi 2010). Eppler (2006) considers concept mapping strategy as a tool for promoting reflection of students' learning and Erasmus (2013) maintain that it fosters student engagement. Concept mapping has been used to face the challenges of meeting the multidimensional nature of science subjects in the field of science education. Research studies of concept mapping strategy entail that it has been used as an effective diagnostic tool to evaluate student's understanding and misconceptions (Mintzes & Wallace 1990; Ross & Munby 1991; Jack 2013; Emmanuel 2013), for assessing learning processes and as an alternative to science assessment in classrooms (Fleener & Marek 1992; Meerah *et.al.* 2013; Soika & Reiska 2014). Wallace and Mintzes (1990) in their study of concept maps concluded that concept mapping is an effective tool to record conceptual change in learners. This is in agreement with Novak (1980) who developed concept maps as useful tools to help students learn the process of learning. Several researches require the learner to operate at all six levels of cognition of revised Bloom's taxonomy such as remembering, comprehending, applying, analysing, evaluating and creating when learning with concept maps (Novak & Cañas 2007; Adlaon 2012; Nesbit & Adesope 2006; Awofala 2011; Boujaoude & Attieh 2008). Although Boujaoude and Attieh's (2008) investigation on the effect of concept mapping strategy on achievement in chemistry that involved 60 tenth grade students, showed that the effectiveness of concept mapping is small compared to the other expository methods of instruction. The study concluded that there was significant correlations between students' post test scores on higher order questions. These findings are in agreement with Novak & Gowin (1984) and Novak & Cañas (2007) as they demonstrated that concept mapping instructional strategy is effective in measuring different attributes of students' abilities, specifically in solving higher order level questions while traditional assessments measure lower order cognitive skills. This was supported by Oosterhof (1994) claiming the possibility of measuring higher order abilities using appropriately designed assessments. Awofala (2011) in his study concludes that the concept mapping strategy has the ability to enhance mastery of content at higher order levels of cognition.

Horton *et.al.* (1993) and Nesbit and Adesope (2006) `in their meta-analysis study reviewed quantitative studies related to use of concept mapping in teaching and learning and found that use of concept maps increased knowledge retention and knowledge transfer in comparison with other activities. Their meta- analysis study encourage teachers, instructional designers, curriculum developers to use concept mapping as an instructional tool in wide range of educational settings. Soika and Reiska (2014) reported in their study that concept mapping as an evaluation tool is indispensable even in large scale studies as it provides a visualization of the student's knowledge structure. Correia (2014) investigated neighborhood analysis to foster meaningful learning using concept maps and concluded that they are applicable for assessing science lessons at secondary and higher level if the instructor deals with the cognitive conflicts of students and providing scaffolding and timely feedback. Kinchin (2014) in his study recommended the use of concept mapping in compatible curriculum settings so that the constructivist foundations of the strategy are reflected and should be utilized as a research tool in learning. This was in agreement with the recommendations of several other related studies (Novak 1990; Novak & Gowin; Novak & Cañas 2007; Novak 2010).

2.3.2 Concept mapping in various discipline of studies

Several studies have found the use of concept mapping strategy very effective in teaching and learning difficult concepts across different subjects, in mathematics (Awofala & Awofala 2011; Awofala 2011), in biology (Udeani & Okafor 2012; Dong 2013; Adlaon 2012) in physics (Karakuyu 2010; Martínez et. al., 2012), in chemistry (Emmanuel 2013; Jack 2013; Burrows &Mooring 2015; Meerah *et.al*. 2013) in English literature (Leahy 1989; Villalon & Calvo 2011). According to Leahy (1989), concept mapping strategy can be adopted effectively in learning literature in which students can link characters, actions, and symbols which are the concepts in literature and make a network of content ideas to exhibit what they have learned. They can also use concept mapping to condense their experience through reading and give reflections. These research studies concluded that the concept mapping is a valid tool in teaching and learning. Several research studies revealed that concept mapping is a valid and reliable teaching and learning tool in higher education (Markow & Lonning 1998; Hay 2007; Hay, Kinchin & Lygo-Baker 2008; Grice 2016), especially in nursing education (Lee *et. al.* 2013; Hunter Revell 2012; Gerdeman, Lux & Jacko 2013) and in enhancing critical thinking in nursing students (Wheeler & Collins 2003; Nirmala & Shakuntala 2011; Kaddoura, Van-Dyke & Yang 2016). However, a very few have addressed the effectiveness of concept mapping strategy at the elementary level. The practice of using concept maps as an instructional tool is becoming more extensive in the areas of science and mathematics education.

2.3.3 Effects of Concept Mapping on Students' Academic Achievement in Science/Chemistry

Emmanuel (2013) used a quasi-experimental study to investigate the effects of concept mapping strategy on the achievement in chemistry of 1357 secondary school students in Nigeria. The study reported that the students taught using concept mapping strategy achieved higher scores than those taught by traditional teaching strategy. The study recommended to provide adequate training to teachers on the use of concept maps to teach difficult concepts in secondary level. These findings are in agreement with findings of several research studies that investigated the effects of concept mapping strategy on the academic achievement of students in chemistry (Jack 2013; Meerah *et. al.* 2013; Burrows & Mooring 2015). Meerah *et.al.* (2013) in their study have provided empirical evidence of the effectiveness of concept mapping as reliable techniques to foster thinking in chemistry lessons, especially on topics such as atomic structure, the periodic table and chemical bonding. Jack (2013) in his comparative study concluded that concept mapping approach was more effective in facilitating meaningful understanding of chemistry concepts which favored long time retention of information and was superior to even guided inquiry approach, which is considered as one of the effective methods in science instruction. This may be due to lack of background information and comprehension of concepts. This can be solved by encouraging students' active participation in constructing concept maps of the learning material which can help students create a cognitive schema to integrate and relate new information (Guastello, Beasley & Sinatra 2000). Concept mapping strategy was recommended as the most effective instructional strategy over expository and guided inquiry methods of instructions by pointing out that strong conceptual understanding is relevant for inquiry lessons to be meaningful and effective (Jack 2013). This finding supported the similar study made by Karakuyu (2010) in physics achievement. In his study, Karakuyu (2010) claimed that students who were taught by concept mapping strategy not only performed better in the physics achievement test but also developed a positive attitude towards the subject and learning using concept mapping strategy. This was in agreement with Markow and Lonning's (1998) findings in their study of the use of concept maps in college chemistry labs which claimed that a positive attitude has developed towards learning using concept mapping. Dong (2013) reported that English Language learners (ELL's) can understand difficult science concepts if the teacher uses concept mapping strategy in instruction that can connect their pre-existing knowledge of science concepts in their native language to new information. Impact of concept mapping in improving EFL learners' understanding of concepts and critical thinking ability were studied and proven by Khodadady and Ghanizadeh (2011). Ameyaw (2015) has proved concept mapping as an effective technique in improving teaching and learning in Glycolysis and Kerb's cycle. Majority of these researchers who investigated the effectiveness of concept mapping on student achievement in different disciplines of studies, have administered a pre-test – post-test achievement test for an experimental and control group. The research questions were addressed using mean and standard deviation scores. Various statistical techniques are employed to analyse data in related studies such as descriptive statistics, inferential statistics, t-tests, analysis of variance (ANOVA) as well as 2 way analysis of covariance (ANCOVA) depending upon the variables.

Chapter Three: Research Methodology

There are several studies which have investigated the effectiveness of concept mapping as a constructivist instructional tool on the academic achievement of students in different areas of science by employing a quasi-experimental research method (Adlaon 2012; Jack 2013; Chularut & Oklahoma 2001; Cheema & Mirza 2013; Karakuyu 2010; Emmanuel 2013). However, there are limited studies on the effectiveness of concept mapping on the academic achievement of middle school students in the Middle East and are well less documented. The purpose of this investigation is to determine the effect of concept mapping as an instructional strategy on students' academic achievement in chemistry at the middle school level. In this Chapter the quasi experimental research method employed in the present study and information about the site, participants, instruments and ethical considerations have been briefly discussed.

3.1 Research Design

A quantitative approach is believed to be the most powerful and appropriate research approach that can establish cause- and- effect relationships which directly influence a particular variable. Quasi- experimental method is the most dependable method in which one or more interventions are scientifically differed in order to determine the effect of the variation produced during the investigation. The present study is aimed at determining the cause and effect relationships between selected variables assigned for an experimental group and control group using a pre-test post-test design. The nature of the intervention and intact nature of the groups justify the use of quasi-experimental research design as the most suitable design for the present study (Fraenkel, Wallen & Hyun 2012, 2015; Slavin 2011; McMillan & Schumacher 2010; Mertens 2010). There has been comprehensive research studies similar to the present study as indicated in Chapter 2, which contributed to the study of the effectiveness of concept mapping on students' academic achievement, has successfully employed the quasi experimental research design for the purpose of their study (Karakuyu 2010; Meerah *et.al.* 2013; Emmanuel 2013).

Quasi experimental designs are "almost true experimental designs" (Mertens 2010, p.138) with an exception that researcher does not assign participants into groups randomly as in true experimental designs, instead studies how the intact groups are affected by the intervention (Mertens 2010; Lodico, Spaulding and Voegtle, 2010). According to McMillan & Schumacher (2010, p.278) quasi experimental method is usually reliable over pre experimental designs as "they provide rational control over most sources of invalidity". The reliability of quasi experimental research design over true experimental designs has been also claimed by many researchers in the field of educational research (Cohen, Manion & Morrison 2007, p. 283; Creswell 2012, p.309, Fraenkel, Wallen & Hyun 2012, p.268, Fraenkel, Wallen & Hyun 2015, p. 275) by pointing out that, in true experiments there is difficulty in random assignment of subjects to control and experimental groups, unavailability of control or comparison groups, practical difficulties and high cost (Lodico, Spaulding and Voegtle, 2010; McMillan & Schumacher 2010, p.278).

To fulfil the purpose of the study to determine the cause and effect relationship between concept mapping instructional strategy and students' academic achievement in chemistry, non-equivalent groups pretest-posttest experimental design was utilized as it can maintain reasonable control over most sources of invalidity and there is nonrandomized selection of samples (McMillan & Schumacher 2010; Creswell 2012). A research design with naturally occurring comparisons groups is chosen to be as alike as possible. The pretest-posttest non-equivalent groups designs with naturally occurring comparisons are claimed to be very prevalent and useful in education Fraenkel, Wallen & Hyun 2015, p.275; McMillan & Schumacher 2010) in which the "researcher uses intact groups of subjects, administers a pretest, provides the intervention condition to one group and finally administers the posttest" (McMillan & Schumacher 2010, p.278; Fraenkel, Wallen & Hyun 2015, p.275, Mertens 2010). A diagrammatic representation of study design is given in Figure 3.1 where X1 represents an intervention given by means of concept mapping, X2 represents the conventional teaching that do not involve a presentation of concept maps in learning the specified topic. E1 indicates experimental group and E2 represents control group, O1 and O2 are pretest and posttest respectively of E1 group while O3 and O4 are pre and post-tests respectively of E2 group.

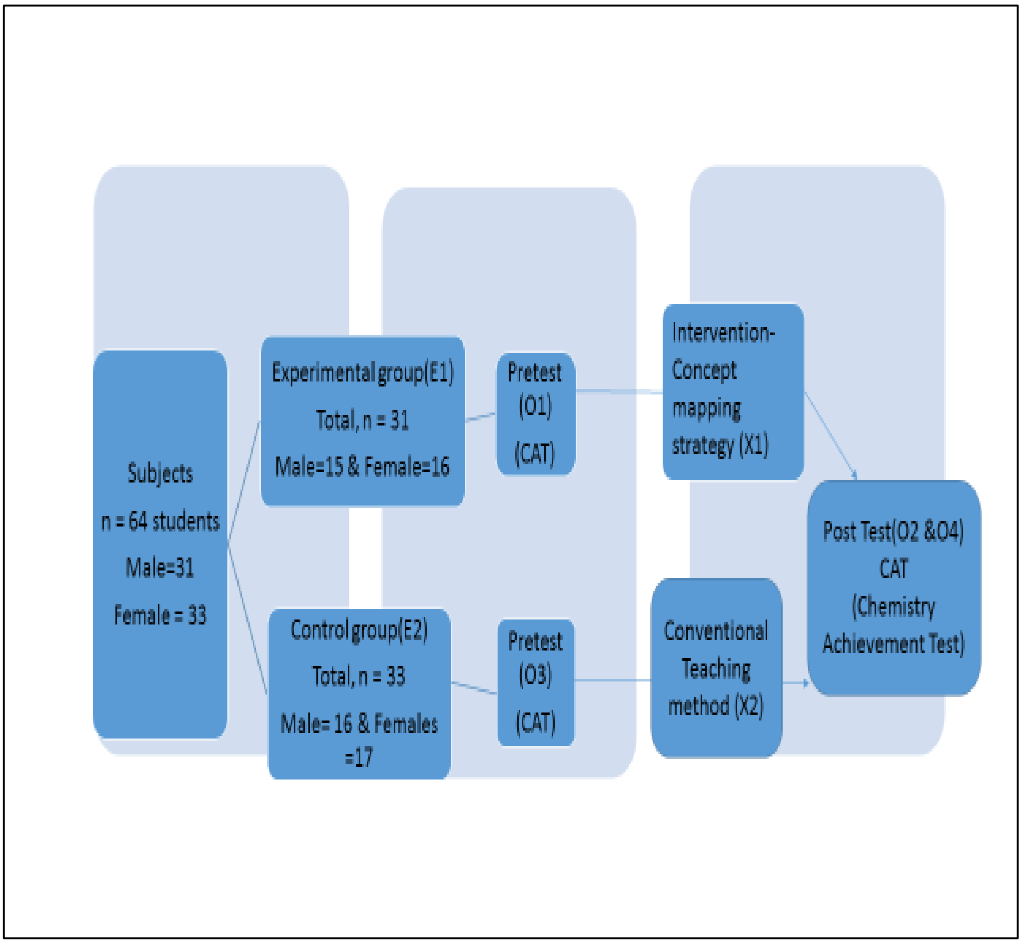

Figure 3.1. A horizontal hierarchical representation of the current Study plan.

In the present study, the researcher has tried her level best to keep the control group as similar as possible in terms of their age group, intelligence level, teacher factor, duration of the instruction etc. The independent variable is the concept mapping teaching strategy and dependent variable is the student's achievement in chemistry in the current study and all these variables play a significant part in this study.

The independent and dependent variables in the present study are defined as follows:

Concept Mapping: is a metacognitive pedagogical and assessment tool to help students learn how to learn by visualizing the relationships among different concepts and by suggesting links between students' existing ideas and new concepts to be learned (Novak & Gowin 1984; Jonassen, Beissner & Yacci 1993; Liu & Hinchey 1996; Asan 2007).

Student Achievement: is a measure of what has been learned by the student (McMillan &Schumacher 2010).

This study was an effort to find out the effect of concept mapping as an instructional strategy on grade seven students' academic achievement in chemistry as signified in Chapter 1.

To achieve this purpose, the following research questions were pursued:

1. To what extent does the concept mapping strategy affect students' academic achievement in chemistry?
2. To what extent does concept mapping strategy affects the students' achievement
   scores in higher order cognitive objectives such as analysing, evaluating and creating levels of chemistry instruction?

Hypotheses formulated for the study are as follows:

1. There would be a significant difference between the achievements of grade seven students taught by concept mapping strategy than that of those taught by the lecture method.
2. There would be significant differences in the students' achievement scores in analysing, evaluating and creating levels of cognition after being taught by concept mapping strategy and conventional method.

3.2 Participants, Site and Course Content Selection

The site of the current study is a K12 private school in Dubai, offering British (Cambridge IGCSE) curriculum. The medium of instruction is English. The school was established in 1995 and has over 900 students studying from Kindergarten to Grade 12. Male and female students study separately from grade 5 up to grade 12.

The participants were from similar cultural back ground, socio economic status and 100% of the participants of this study were native Arabic speakers who received their education in the medium of English. The participants in this study consisted of sixty four (64) grade 7 students comprised of thirty one (31) males and thirty three (33) females.

There are over 75 teachers in the whole school inclusive of 11 science teachers, who are well qualified, experienced, knowledgeable and skilled in their areas of study. Science is considered as a relevant discipline of study in the school which has a mission of fostering scientific literacy in students by inspiring and enhancing meaningful learning of science concepts. The science department is strongly supported by the science faculty, leaders and parents in order to achieve this goal. The researcher who is also a member of the science faculty of the school, has 12 years of experience in science teaching which includes 8 years in the middle east, facilitates science learning for students in middle school (Grades 7 and 8) who will be investigating the effect of concept mapping on the academic achievement of her grade 7 students in chemistry. The subjects were from inclusion classes, but in order to increase the internal validity, the data from the inclusion students were excluded due to nature of their disabilities, IEP accommodations and difference in their achievement levels that can directly influence the independent variables. In the present study the experimental group was intervened with concept mapping instructional strategy and the control group was exposed to teacher centered regular teaching method.

A stratified random sampling was employed (McMillan & Schumacher 2010, p.134; Fraenkel, Wallen & Hyun 2015, p.96) in the present study in which the researcher did an equivalent distribution of students from intact groups into experimental and control groups. According to Fraenkel, Wallen & Hyun 2015, p.96, stratified random sampling virtually ensures that key characteristics of individuals in the population are included in the same proportions in the sample, especially when the sample size is not too large. The researcher divided the subjects into subgroups or strata on the basis of variables chosen. The sample is diagrammed in Figure 3.2, where E1 is Experimental group and E2 is control group. Students were given a brief explanation about the research study especially the purpose, procedure, duration and their role in the study.

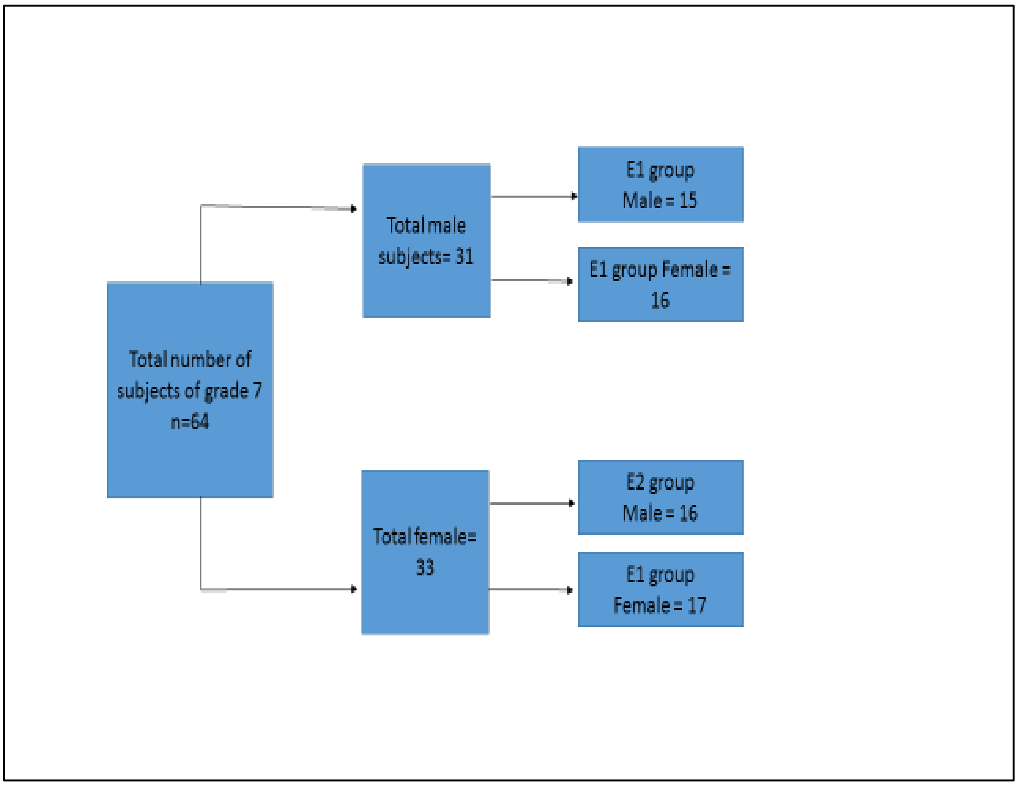

Fig. 3.2. Stratified random Sampling

The topic selected for the present study was States of Matter but the instruction was limited to subtopics such as Solids, Liquids and Gases, Particle theory of matter, Change of states and Diffusion. This unit was structured hierarchically and was well suited for teaching using concept mapping strategy. One advantage was that the topic can be taught at higher order levels of cognition such as analysing, evaluating and creating.

The researcher used the average science achievement scores of Term 1 examination of each group in order to keep the control group as similar as possible to the experimental group along with providing instruction of same duration to each group for both concept mapping instructional method and regular teacher centered method respectively. Table 3.1.represents average of participants' science achievement scores in Term 1 examination categorized by gender and group.

Group	Gender	Number of participants	Average	Standard Deviation (SD)
Experimental Group (E1)	Male	15	74.46	12.60
	Female	16	74.31	11.8
Control Group (E2)	Male	16	73.75	12.46
	Female	17	73.94	11.94

Table 3.1. Students' science achievement scores in Term 1 examination categorized by gender and group.

3.3 Instrumentation

One instrument used in the present study was a CMAT (Chemistry Matter Achievement Test), which was administered as a pretest at the beginning of the study and as a posttest at the end of the study, to both control and experimental groups to collect data. The achievement test covered the selected content from Stage 7 Science Main Course book.

CMAT (Chemistry Matter Achievement Test) was constructed with reference to revised Bloom's Taxonomy of educational objectives (Appendix 8). The items included in the test were intended to examine the attainment of students' in seven different levels of cognition such as remembering, comprehending, applying, analysing, evaluating and creating (Bloom 1969; Anderson and Krathwohl 2001). A blue print was created taken into account factors like weightage to content, objectives and different levels of cognition that covered all the topics of the study which is represented in Table 3.2. Some of the items of the test was developed by the researcher herself and some were collected from different sources like

Cambridge checkpoint science textbooks, and work books, Cambridge check point past papers, NCERT science text books and then compiled by the reseracher in CMAT.

Objectives	Remember		Understand		Apply		Analyse		Evaluate		Create		Total
Form of questions / Content	Mcq	SA	Mcq	SA	Mcq	SA	Mcq	SA	Mcq	SA	Mcq	SA	
States of Matter	1	2		4		3		2		1			13
Particle Theory		2			1					4		5	12
Changing states			1		1	1	1	4	1	1			10
Total	5		5		6		7		7		5		35

Mcq – Multiple choice questions

SA – Short answer Questions

Table 3.2. Blue Print of CMAT

3.4 Pilot Study

The instrument was piloted in a different British curriculum School with thirty six (36) grade 7 students to ensure its reliability and validity as recommended by Fraenkel, Wallen and Hyun (2012, 2015). The content of the test was reviewed and checked by six chemistry subject experts who are holders of Masters degree or Doctorate degree in Chemistry and has a teaching qualification such as B.Ed or PGCE in Science education and with over 9 years of expereince in School or College teaching, and this has ensured the accuracy of content and vocabulary of the CMAT. The subject experts include the researcher's head of the science department, curriculum coordinator, three science teachers from different British curriculum schools and a friend of the scholar who has a doctorate degree in chemistry. A few words in some of the CMAT items were modified and revised based on the results of pilot study data. Issues with reading and comprehending skills in english language were also considered while modifying the test items to suit the learning needs of native speakers of arabic.

According to Fraenkel, Wallen and Hyun (2012, 2015, p.148), "validity refers to the appropriateness, meaningfulness, correctness, and usefulness of the inferences a researcher makes". They further claim the relevance of the concepts, internal and external validity in the designing and evaluation of the instrument. In the present study, the internal validity was focused on assessing what the CMAT was supposed to measure and the external validity was focused on the possibility of generalization of the findings to the population of the study and how well the research literature and theories support the elucidation of the data (Creswell 2012).

"Reliability refers to consistency of scores or answers from one administration of an instrument to another, and from one set of items to another" (Fraenkel, Wallen & Hyun 2012, 2015, p.148). The reliability result of Cronbach's-Alpha test was found to be 0.866 (α= 0.866) which is considered to be a high level of internal consistency for the 26 test items.

3.5 Procedure, Data collection and Analysis

The researcher herself served as the science teacher for both the control and the experimental group. The CMAT was administered as a pretest to the experimental and the control group at the same time before the intervention. Thereafter, the two groups were taught the content selected by the researcher for four weeks, where each week consisted of 5 science lessons with a duration of 45 minutes each. The teacher introduced the lesson and communicated the learning objectives to the subjects in the experimental and control groups. The main concepts in the lesson, States of matter were taught using concept maps (Appendix 5) to the participants in the experimental group. In the control group, the teacher introduced the lesson and objectives to the participants and the main content is taught using a lesson plan which involved a lecture method without any use of concept maps. Efforts were made to reduce differences in teaching styles, use of resources like text books, work book, worksheets, videos etc. Both the control and the experimental groups were given the same test which was administered as the pretest at the beginning of the study, as the posttest in the fourth week that is at the end of the intervention, to measure the learning that had taken place. The researcher analysed the quantitative data generated using the pretest and posttest scores.

The pretest and posttest scores of experimental group, consisted of 31 students and the control group, consisted of 33 students have been statistically analysed using Statistical Package for Social Science (SPSS) software. The researcher has employed descriptive statistical techniques such as mean and standard deviation and inferential statistical techniques such as paired and independent *t* tests (Fraenkel, Wallen & Hyun 2015, p. 234) in the current study and answered the questions under study by determining the statistical significance of the differences in the mean of the pretest and posttest scores of the CMAT (Field 2009; McMillan & Schumacher 2010; Mertens 2010; Fraenkel, Wallen &Hyun 2015).

The analysis and interpretation of data are presented in Chapter Four.

3.6 Ethical Considerations

The school management and participants were informed in detail about the purpose and nature of the study. For ethical reasons, an informed consent form developed by the researcher was given to the principal of the school and participants of the study to sign before they engage in the research study which includes an assurance of confidentiality of information they provide and the protection of their rights during the research (Creswell 2009). This includes, the name of the school, name of the participants, learning difficulties of the participants etc. There should be a mutual agreement between the participants and the researcher, ensuring confidentiality of research data which Fraenkel, Wallen &Hyun (2015) called an ethical research. The researcher being the science teacher of both the study groups and the topic being a course content of grade 7, none of the groups were disadvantaged in terms of duration of instruction or studying an extra content not in the curriculum of their study. The consent forms developed by the researcher given to the principal and the students are included in the Appendix (Appendices 2 and 3).

Chapter Four: Data Analysis and Results

This chapter describes and analyses the data collected from pre-test and post test scores of the Chemistry Matter Achievement Test (CMAT). To fulfil the purpose of the study, a non-equivalent group's pretest-posttest quasi experimental design was employed to determine the cause and effect relationship between concept mapping approach and students' academic achievement in chemistry. The purpose of this investigation is to determine the effect of concept mapping as an instructional strategy (independent variable) on students' academic achievement (dependent variable) in chemistry at the middle school level. A comparison of the pre-test and post-test scores of experimental and control groups were utilized to explain the effects of the independent variable on the dependent variable to address the two main research questions,

1. To what extent does the concept mapping strategy affect students' academic achievement in chemistry?
2. To what extent does concept mapping strategy affects the students' achievement
   scores in higher order cognitive objectives such as analysing, evaluating and creating levels of chemistry instruction?

The participants in this study consisted of sixty four (64) grade 7 students comprised of thirty one (31) males and thirty three (33) females in a British Curriculum School in Dubai that follows Cambridge check point curriculum at the primary and the middle school levels and IGCSE at the high school level. Table 4. 1 represents the distribution of the subjects categorized by gender and groups, where n is the number of subjects and % is the percentage of subjects in each group.

		Male		Female		Total	
Study Groups		n	%	n	%	n	%
	Experimental Group (E1)	15	48	16	52	31	48
	Control Group (E2)	16	48	17	52	33	52

Table 4.1. The distribution of the subjects categorized by gender

In the present study data collected were analysed by utilizing descriptive and inferential statistics (independent *t* test and paired *t* test) for the analysis of different data to test the two hypotheses of this study. Descriptive statistics were used to compare the mean pre-test and post-test scores of the experimental group and control group in the study and to report the statistical significant difference between them. Inferential statistical methods such as a paired *t* test was employed to compare the independent variable within each group to determine whether there is any statistical significant differences between the mean scores of pretest and posttest within each group. The *t* test compares the means of two groups and compares the differences in variables between two groups.

First, an independent *t* test was employed to analyse the data collected from the pre-test scores of control and experimental groups, to measure the effects of independent variable, concept mapping approach on the dependent variable, and students' academic achievement in chemistry. This test results would determine the equivalency and adequacy in sampling in groups that enter the intervention. Second, a paired *t* test was employed to compare the effect of independent variable on dependent variable within each group to determine whether there is any statistical difference between mean pre-test and post-test scores within the experimental and control groups. Third, an independent *t* test was applied to analyse the data collected from the post-test scores of experimental and control groups under the educational objectives of higher levels of cognition such as analysis, evaluating and creating in the chemistry achievement test.

4.1 Equivalency of Experimental and Control Groups.

The experimental and control groups were pretested and the results were compared to determine whether the equivalency of the groups and adequacy in sampling. The pre-tests were done at the beginning of the study before the topics were taught with concept mapping as an intervention. Descriptive statistics using mean and standard deviation and inferential statistics using independent *t* test was employed and p value was calculated. The table 4.2 represents the statistical results.

Group	Number of Students (N)	Mean (M)	Standard Deviation (SD)	Independent *t* test	Degree of freedom (df)	Level of significance (p*)
Experimental(E1)	31	14.12	3.02	1.13	62	0.26
Control(E2)	33	13.33	2.52			

*** p is statistically significant at p∠ 0.05**

Table 4.2. Difference between the Pre-test Achievement Scores of Experimental and Control Groups

According to the results table there is no significant difference in the pre-test scores for experimental and control group in the CMAT test. The statistical results with a mean of 14.12 and standard deviation of 3.02 for the experimental group and a mean of 13.33 and standard deviation of 2.52 for the control group with a calculated t (62) test result of 1.13 and p value of 0.26 ($p>0.05$) indicates that there is no significant difference in the CMAT pre-test scores for experimental and control groups.

4.2 Difference between the Achievement Scores of Experimental and Control groups

This section includes the descriptive and inferential statistics of CMAT scores to find out the effects of concept mapping approach on students' academic achievement in the test. The first level of analysis is to measure the relationship between the pre and post-tests mean scores within experimental and control groups.

The next level will be to compare the post-test mean scores of experimental group with that of the control group.

4.2.1 Difference between the Pre and Post-test Achievement scores within experimental and Control Groups

The pre-test and post-test scores of participants within the same group are compared and explained using descriptive and inferential statistical methods. A paired t test was applied to find out whether there is any significant difference in the CMAT pre and post test scores of students within the same group. Table 4.3 represents the descriptive and inferential statistics of CMAT scores for experimental and control groups.

Groups	Tests	N	M	SD	df	Paired *t* test	p
Experimental E1	**Pre (O1)**	**31**	**14.12**	**3.01**	**30**	**-19.88**	**0.000**
	Post (O3)	**31**	**21.38**	**3.49**			
Control E2	**Pre (O2)**	**33**	**13.33**	**2.52**	**32**	**-22.22**	**0.000**
	Post (O4)	**33**	**17.87**	**2.52**			

Table 4.3. Descriptive Statistics and Paired T-Test Results between the CMAT Pre-Post Scores of Experimental and Control Groups

As shown in the table 4.3, the paired *t* test results for experimental group, $t(30) = -19.88$ and value of $p \angle 0.05$ shows that there is a significant difference in the pre and post test scores of students with in the experimental group. It is found that there is also a significant difference in the pre and post test scores of students within the control group as determined by the paired *t* test, t (32) = -22.22 and p∠ 0.05.The descriptive and inferential statistic results explain that the experimental group and control group have achieved better scores in the CMAT post-test than the pre-test irrespective of the teaching intervention they have received during the period of this study. Figure 4.2 represents the mean pre and post test scores of experimental and control group in the CMAT test.

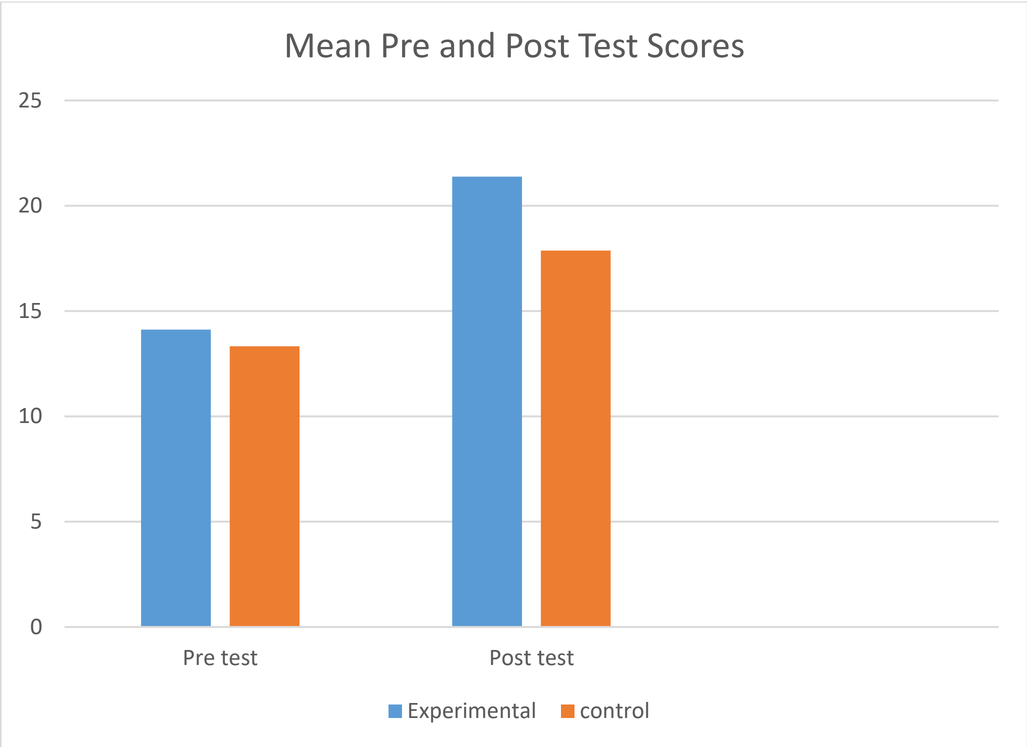

Figure 4.1. Difference between Mean CMAT Pre and Post Test Scores of Experimental and Control Groups.

The graph shows that there is no significant difference in the mean pre-test scores of the experimental and control groups. However, there is a significant difference found in the mean post test scores of the experimental and control groups. The graph also shows that there is a significant difference in the mean pre and post-test scores within the experimental and control groups as a result of descriptive and inferential statistics in which paired *t* test was applied.

4.2.2 Difference in the Post-test Achievement Scores of Experimental and Control Groups

Descriptive statistics using mean and standard deviation and inferential statistics using independent *t* test was employed to compare the CMAT post-test scores for Experimental and Control groups. Table 4.4 represents the statistical results.

Group	N	M	SD	df	Independent t test	p
Experimental (E1)	**31**	**21.3**	**3.32**			
Control (E2)	**33**	**17.9**	**2.52**	**62**	**4.632**	**0.0001**

Table 4.4 Descriptive and Independent *t* Tests Results of CMAT Post Scores for Experimental and Control Groups.

As shown in the table, the independent *t* test results indicate a high significant value for p∠0.05 with a calculated *t* test result of t (62) = 4.632. These results accept the first hypothesis:

- *H.O 1. There would be a significant difference between the achievements of grade seven students taught by concept mapping strategy than that of those taught by the lecture method.*

There is a significant difference in the CMAT post test scores for experimental and control group after being taught by using concept mapping method and traditional teaching method respectively. The mean scores of the experimental group is higher than that of the control group, which indicates that the experimental group is far superior than the control group with regard to the achievement in chemistry.

The following graph (figure 4.2) represents the results of independent t test which summarizes the comparison between the mean post test scores of the experimental and control group.

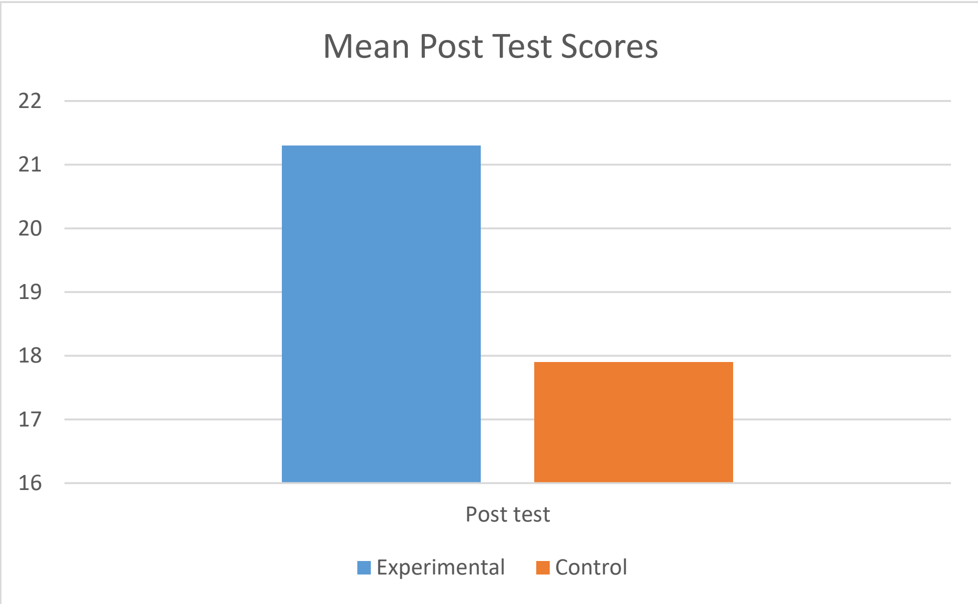

Figure 4.2. Mean CMAT Post Test Scores of Experimental and Control Groups.

The graph shows that there is a significant difference in the mean post test scores of experimental and control group which proves that the use of concept mapping as an instructional strategy can increase the academic achievement of students than those who were not exposed to concept mapping strategy.

4.3 Effect of Concept Mapping Approach on Achievement Scores at Higher Levels of Cognition

Descriptive statistics and independent t tests were used to compare the mean CMAT post test scores on the analysing, evaluating and creating components of the test for the experimental and control groups. The results are represented in table 4.5.

Taxonomy	Group	N	M	SD	df	Independent t test	p
Analysing	**Experimental** **Control**	**31** **33**	**3.61** **2.52**	**0.80** **0.71**	**62**	**5.792**	**0.0001**
Evaluating	**Experimental** **Control**	**31** **33**	**3.26** **2.39**	**0.68** **0.56**	**62**	**5.574**	**0.0001**
Creating	**Experimental** **Control**	**31** **33**	**2.48** **1.06**	**1.00** **0.70**	**62**	**6.633**	**0.0001**

Table 4.5. Comparison of Students' Post-test Analysing, Evaluating and Creating scores

As shown in table 4.5, students' mean post test scores in the analysing, evaluating and creating levels of cognition of the experimental and control groups indicate that the experimental group had greater gains in the higher order levels of cognition in the post-test than the control group. The results indicated significant outcomes in the students' scores at analysing level ($t\ (62) = 5.792$, $p \angle 0.05$), evaluating level ($t\ (62) = 5.574$, $p \angle 0.05$) and creating level ($t\ (62) = 6.633$, $p \angle 0.05$) of cognition. These differences showed that the students exposed to concept mapping approach achieved better than those exposed to traditional teaching method at their higher levels of cognition in the CMAT test. These results accept the second hypothesis,

H.O 2. There would be significant differences in the students' achievement scores in analysing, evaluating and creating levels of cognition after being taught by concept mapping strategy and conventional method.

The following graph (figure 4.3) summarizes the effect of concept mapping on the academic achievement of students in the CMAT in the higher levels of cognition such as analysing, evaluating and creating.

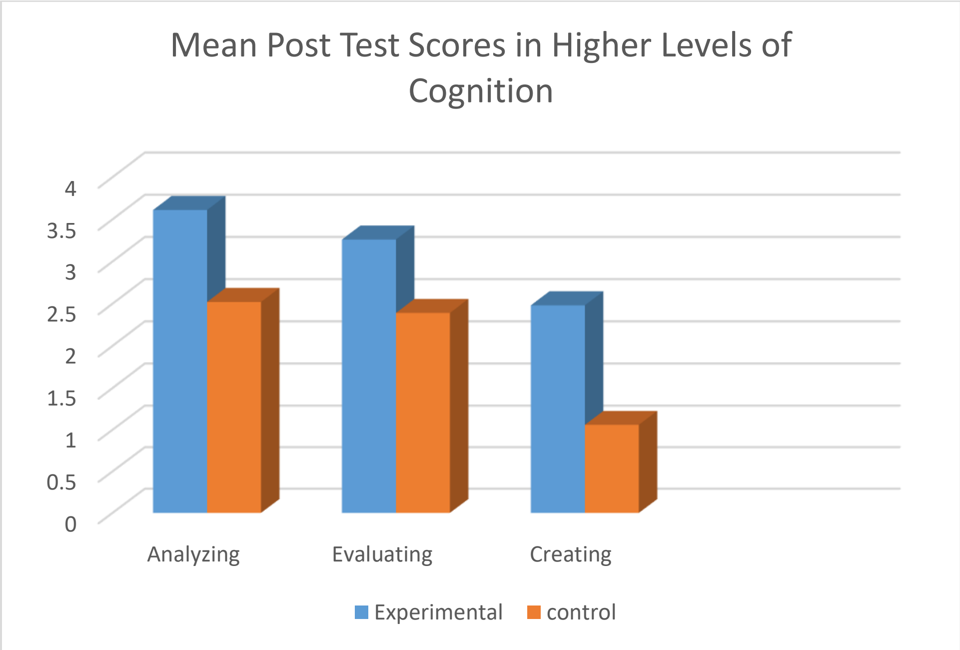

Figure 4.3 Comparison of Students' Post Test Analysing, Evaluating and Creating Scores for Experimental and Control Groups.

The figure 4.3 indicate that there is a significant difference in the mean post-test analysing, evaluating and creating scores of the experimental and control groups. This concedes that students who were exposed to concept mapping strategy significantly achieved better than those who were not exposed to concept mapping strategy at their higher levels of cognition such as analysing, evaluating and creating. These outcomes accept the second hypothesis of the current study.

These outcomes corroborate the findings that using concept mapping as an instructional strategy have positively affected the students' academic achievement in chemistry as well as their higher levels of cognition. Thus, based on the above findings, it can be concluded that there has been an increase in the academic achievement of students in the experimental group than the students in the control group. The following chapter will discuss these outcomes in light of previous studies, and make suitable recommendations in the area of enhancing meaningful learning of chemistry concepts by using concept mapping as an instructional strategy.

Chapter Five : Discussions, Recommendations, Conclusions and Limitations

This chapter discusses the outcomes of the present study, conclusions and recommendations for further research.

5.1 Discussions

The present study aimed at determining the effect of concept mapping as an instructional strategy on students' academic achievement in chemistry at the middle school level. The variables were assigned for an experimental group and control group using a pre- posttests quasi experimental design to address the main research questions:

1. To what extent does the concept mapping strategy affect students' academic achievement in chemistry?
2. To what extent does concept mapping strategy affects the students' achievement
   scores in higher order cognitive objectives such as analysing, evaluating and creating levels of chemistry instruction?

The instrument was piloted to ensure the reliability of the test items and was found to have a high reliability. It was also validated by a panel of teachers consisted of 6 members. Data collected were analysed to determine the cause and effect relationships between variables to address the study questions. Pre and post test scores of the achievement test in chemistry were compared to test the study's hypothesis:

- *H.O 1. There would be a significant difference between the achievements of grade seven students taught by concept mapping strategy than that of those taught by the lecture method.*

The CMAT administered was to determine the effectiveness of concept mapping approach in enhancing meaningful learning in chemistry concepts and it was found that there is a significant high improvement in the achievement scores of students who were exposed to concept mapping strategy than those who were not exposed to concept mapping strategy. The paired *t* test results that analysed the effects of independent variable on the dependent variable with in the groups indicated that there is a significant difference between the pre and post CMAT test achievement scores with in the experimental and control groups. The independent *t* test results that analysed the CMAT post-test achievement scores between the experiment and control groups indicated a high statistical significant difference. These outcomes fulfilled the first study hypothesis. These outcomes are in agreement with findings of several research studies that investigated the effects of concept mapping strategy on the academic achievement of students in chemistry/science and other various discipline of studies (Jack 2013; Meerah *et. al*. 2013; Burrows & Mooring 2015; Awofala 2011; Udeani & Okafor 2012; Cheema & Mirza 2013; Emanuel 2013) and corroborating the findings of these studies which showed that concept mapping approach was more effective than other strategies of instruction in enhancing students' meaningful learning of concepts and has improved students' academic achievement scores. The influence of concept mapping approach on students' academic achievement in the current study is obvious and may be attributed to the constructivist and metacognitive nature of the use of concept mapping in instructional activities. In this study, the concept mapping strategy in instruction has improved students' academic performance in an achievement test on the topic matter. This may be because the concept mapping strategy has enhanced students' understanding of the chemistry concepts as the hierarchical representation of concepts helped students to develop meaningful relationships between concepts and reach at a lucid, incorporated network of the material of study (Mosley & Draper 2014). Research evidence has denoted that concept maps are effective as they allow students to structure and organize their conception of knowledge (Novak & Gowin 1984). Concept mapping is based on visual imagery and are easily comprehended than the words that represent an abstract information (Terry 2003) and they are significant as the prior knowledge which has qualitatively and quantitatively different knowledge structures is visible in it (Hay, Kinchin & Lygo-Baker 2008) and this is further linked to new ideas. This kind of visually represented information promotes meaningful conceptual learning and long-time retention of concepts learned (Popuva-Gonci & Lamb 2012; Guastello, Beasley, & Sinatra 2000). In this study concept mapping approach has undoubtedly enhanced the retention of concepts for a long time in participants of the experimental group and consequently increased their post-test achievement scores compared to the control group.

Another interesting outcome in this study is the noticeable significant differences in the post test scores of the experimental and control group at the higher levels of cognition such as analysis, evaluating and creating levels which has fulfilled the second study hypothesis:

H.O 2. There would be significant differences in the students' achievement scores in analysing, evaluating and creating levels of cognition after being taught by concept mapping strategy and conventional method.

The independent *t* test that analysed the effects of concept mapping approach on the CMAT achievement scores at higher levels of cognition between the experimental and control groups was found to have statistical significant difference. These findings concede that concept mapping is an effective pedagogical tool that assesses learners' structural knowledge which arbitrates the rendition between declarative knowledge to procedural knowledge (Jonassen *et. al.* 1993; Awofala 2011) and higher order levels of cognition (Novak, Gowin & Johansen 1983) which transfers knowledge to a great extent. In this study students in the experimental group who are exposed to concept mapping strategy, have developed the skills of breaking down complex and abstract concepts into sub concepts, identify their relationships, linked those sub concepts using connecting lines and phrases and incorporated them into a network of learning material which is meaningful. This was possible because learners have developed skills in making judgments in the arrangement of concepts and in linking those concepts. This has improved the students' understanding of the meaning of concepts and enhanced the academic performance at the higher levels of cognition of the experimental group compared to the control group. These findings corroborate the studies which have proved the effectiveness of concept mapping on the learners' achievement in higher order cognitive abilities and critical thinking skills in chemistry/science and various discipline of studies (Oosterhof 1994; Wheeler & Collins 2003; Boujaoude & Attieh 2008; Awofala 2011; Harris & Zha 2013; Meerah *et.al.* 2013).

5.1.1 Practical Implications

Chemistry being a relevant subject, has a prominent place in the science curriculum of every school. This study has several implications for science/chemistry teachers in the United Arab Emirates (UAE) where the curriculum mainly focuses on concept attainment. Lack of English language skills becomes a barrier along the course of sufficient and successful comprehension of the chemistry concepts. Teaching is effective only if the teaching strategies used are effective for the learner to achieve the desired learning objective and improve student achievement. The findings of this study are encouraging and can be applied to any subject area as it is potential meaningful learning of concepts, especially for students who lack adequate linguistic skills, low comprehension, reasoning and problem solving skills, in addition to the lack of confidence.

The study findings confirm that using concept mapping approach in science, specifically in chemistry learning, will foster meaningful learning and longer retention of concepts. This study also demonstrated that concept mapping approach can enhance mastery of content at the higher levels of cognition which would prepare students for more advanced courses in science. As it has been proved by previous studies and the current study, concept mapping should be preferred by educators as an instructional strategy to enhance meaningful learning over other less effective strategies like dictating the other information. According to Jack (2013), concept mapping approach is superior to guided inquiry approach in instruction due to its constructivist and metacognitive nature. It is recommend that chemistry educators add this to their teaching strategies to teach difficult concepts in chemistry. The study has implications in the academic achievement of students as it has confirmed the importance of concept mapping in enhancing meaningful learning by metacognition and constructivism in learning, by improving cognitive skills, mainly at the higher order levels of cognition and above all develop a genuine interest for science and related disciplines of studies like chemistry, right from the elementary school level. Science educators must use effective strategies like concept mapping in UAE schools, especially with native Arabic speakers, to improve their performance in international standardized assessments like TIMSS, PIRLS or PISA (KHDA 2012, 2013; OECD 2013) as concept mapping strategy can equip students with a range of cognitive skills which is directly linked to student's' attainment and progress in science as recommended by KHDA (2012, 2013) which will undoubtedly corroborate the UAE vision 2021 national agenda.

Teachers adopting this strategy for instruction should improve their knowledge of constructivist learning and metacognitive nature of learning and how this strategy can be effectively employed in the class for instruction and evaluation. The strategy should be included in the chemistry teacher training curriculum so that pre service teachers understand the constructivist and metacognitive nature of the strategy and make effective use of it. Curriculum developers should utilize concept mapping strategy in designing content material

Concept mapping can be used to assess students' prior knowledge and as a formative evaluation tool to examine learners' knowledge structures of specific concepts. This knowledge will help chemistry/science educators to develop meaningful curriculum materials for learning, recognizing the fundamental concepts and connections needed to be taught and addressing the misconceptions and knowledge gaps (Burrows & Mooring 2015) to ensure that students develop a coherent knowledge in the topic. Several research studies support that concept maps can be used as means for identifying knowledge gaps and misconceptions of key ideas, effective instructional planning and curriculum design which leads to meaningful learning, assessment and evaluation, etc. (Novak 1980; Mintzes *et.al*. 1997; Nesbit & Adesope 2006; Novak & Cañas 2006, 2007) and as a tool for promoting reflection of students' learning (Eppler 2006). Text books can be excellent learning resources if relationship between the content ideas of each topic is visually presented as concept maps and related concept mapping activities are included for self-evaluation of students' learning.

5.2 Recommendations

The present study investigated the effectiveness of using concept mapping approach on students' achievement in chemistry as well as their achievement in higher order levels of cognition at the middle school level. The findings of the study indicated that concept mapping is an effective instructional strategy for teaching and learning difficult concepts in chemistry at the middle school level and also is competent to enhance mastery of content at the higher levels of cognition.

The findings of this study are consistent with the theory of cognitive psychology (Ausubel 1968) in which meaningful learning is emphasized than rote learning and epistemological theories of learning in which new knowledge is created. Ausubel's theory is focused on strengthening learner's existing cognitive structure which is a relevant factor in assimilating new ideas. This facilitates their acquisition of new information and its retention for a long time. Novak and Gowin (1984) has developed an instructional theory encompassing concept maps that graphically represents the relationships between new concepts and previous knowledge. The constructivist approaches of learning accentuates on interaction between learner and learning environment and during this interaction prior knowledge is used to elucidate and construct new ideas. Novak & Cañas (2007) emphasized on epistemological foundations of concept maps in their study. Concept mapping is a metacognitive approach that uses affective as well as cognitive skills to promote pattern recognition and enhance meaningful learning (Irvine 1995; Novak & Gowin 1984: Ku & Ho 2010). Several studies have proved the relevance of metacognition and the cognitive and metacognitive nature of concept mapping to facilitate meaningful learning (Novak & Cañas 2007; Novak 2011; Lai 2011; Collins 2011; Veenman 2012). These theories are supported by the findings of this current study that concept mapping strategy can enhance students' academic achievement in the subject as well as positively affect the students' academic achievement at the higher levels of cognition.

Concept mapping remains a promising arena for instructional design, assessment, research, curriculum design etc. Following are the recommendations for further studies, especially within UAE to promote the use of concept mapping method in science instruction as well as in other discipline of studies to increase students' academic performance.

- It is recommended to conduct further research studies for various grades and subjects and with different curriculums.
- A qualitative or quantitative research is suggested to explore the possible effects of gender differences in the use of concept mapping approach, by exploring the learning patterns of different genders.
- It will be also beneficial to study students' reflections about using concept maps in teaching and learning a range of subjects.
- Further research is recommended to explore the effect of concept mapping approach with students with different abilities with in a group.
- Further research is suggested to explore the scope of using concept maps as a summative and formative assessment tools and as a summary of learning material in the text books used in UAE.

5.3 Conclusion

This study highlighted the effectiveness of using concept mapping strategy on the academic achievement of middle school students in a chemistry topic. A pretest-posttest quasi-experimental study design was employed with sixty four middle school students from a British curriculum school in Dubai for a duration of 4 weeks. A reliable and valid Chemistry Matter Achievement Test (CMAT) was administered.

The findings of the study indicated that the concept mapping approach was more effective and superior to the lecture method in teaching and learning science/ chemistry concepts which are aligned with several previous studies (Meerah *et.al*. 2013; Jack 2013; Burrows & Mooring 2015; Emmanuel 2013). It can be concluded that concept mapping has the potential to foster meaningful learning which leads to retention of information for a long time. In the current study, all the students who were exposed to concept mapping performed better in their post-test and also attained higher scores in higher levels of cognition such as analysing, evaluating and creating compared to the students who were not exposed to concept mapping. This is because instruction using concept mapping approach has helped students to identify the relationship among concepts, link their previous knowledge and create new knowledge which has enhanced their cognitive skills due to its metacognitive and constructivist nature. The UAE Vision 2021 National agenda accentuates the need of a complete makeover of the present education system and teaching methods and has set as a target that students in UAE rank among the top 15 in TIMSS and top 20 in PISA exams by 2021. This can be achieved by using effective strategies like concept mapping in science instruction that will foster meaningful learning of concepts and promote longer retention of information which will help students to perform better in science/chemistry achievement tests and also develop interest and positive attitude towards the subject and motivated to pursue higher studies in the subjects which they considered difficult to study.

The findings of this study can provide relevant contributions in the field of education, to understand the need for using strategies such as concept mapping effectively for meaningful instruction, effective curriculum designing, effective evaluation etc. to provide enhanced learning outcomes. Chemistry educators must acquaint with concept mapping in classrooms in the absence of well-equipped laboratories and lack of appropriate instructional aids for hands- on learning as it can be a best alternative to laboratory experience which provides relationships between concepts that will enhance students' performance in the subject. Text books and other learning resources should include concept maps at the end of each lesson as a summary of the learning material. Curriculum planners, science educators and researchers must take cognizance of this innovative method as an effective pedagogical strategy in chemistry classes. However, the government and Ministry of education should provide pre-service and in-service teachers appropriate training on the use of concept mapping in education as an effective pedagogical and evaluation tool. It is hoped that the present study will add to the body of knowledge regarding constructivist and metacognitive learning and will aid in linking the gap that currently exists between these learning theories and its applications in science teaching and learning.

5.4 Limitations

The outcomes of this study are limited in nature and not conclusive as this study involved a limited number of participants who were taught by the scholar. The study involved only grade 7 students in one of the British curriculum schools in Dubai and so do not support the generalizability of the findings. The findings would be qualify for generalization if the research is carried out with a large number of students, for different age groups of students, in different types of schools that follows different curriculums. There were only two sections of grade 7 in the school and so there were limitations in random assignment of participants in study groups and this bias may be threat to internal validity of the study. Another limitations of the study was that it did not consider the possible effects of gender differences in the study groups and could have affected the outcomes of the study. Students' attitude towards the use of concept maps was another limitation as some, however very few, did not have appositive attitude towards the use of concept mapping as a learning tool. Finally, different learning styles were not considered and the concept maps used were not differentiated to meet the individual learning needs of the students within the group.

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https://cct370-w07.wikispaces.com/Cmap

Appendices

Appendix - 1

Letter to School Permission

الجامعة البريطانية في دبي The British University in Dubai

Date: September 15th, 2015

Dear Mr. /Mrs,

The British University in Dubai offers a Master’s of Education (Med) degree to interested students, teachers, and professionals in the United Arab Emirates to maximize their career opportunities and increased their knowledge. The MEd program is designed in collaboration with the School of Education of the University of Birmingham, one of Britain’s leading schools of education. The Med program is approved and accredited by the Ministry of Higher Education and Scientific Research, UAE and has graduated many students since its start in 2005 in several different areas in education. The purpose of this letter is to kindly ask you to allow Nimmy M. Thomas, a student in this program, to be able to conduct a research by conducting experimental study, interviews, survey or observations as appropriate to the study, as would be agreed by your teacher(s) and our student. Data collected will be anonymous and will be treated with utmost confidentiality.

Finally, we look forward to your kind cooperation. If you require any additional information, please don’t hesitate to contact Dr. Sufian Forawi (MEd Program Coordinator) at sufian.forawi@buid.ac.ae or 050 1270746.

Sincerely Yours

Dr. Sufian A. Forawi,

Science Education Associate Professor

Appendix 2 – Researcher's Letter to the School

To Whom It May Concern

I am conducting this research study in the specialization of Education and Leadership from the British University in Dubai. The purpose of the research is to find the effectiveness of concept mapping strategy on the academic achievement of middle school (Grade 7) students in chemistry. The study is hoped to provide relevant contributions in the field of education in enhancing meaningful learning in many subjects.

The data collected from the students' achievement test will be kept confidential and will be used only for this research purpose. Do not hesitate to contact me if you have any enquiries about this research study. Thank you for your cooperation in this academic endeavor.

Best Regards,

Nimmy M. Thomas
nimmuanna@gmail.com
20-10-2015

Appendix 3- Consent Form

PARTICIPANT CONSENT FORM

Provide a brief explanation regarding the purpose of the investigation and the Instrument.

Please tick (√) the following boxes to indicate your agreement:

☐ I have read the purpose of this investigation.

☐ I understand my privacy and confidentiality will be respected and the data collected and its results will not identify any individual participants.

☐ I understand that I have the right to withdraw from this study at any time without preconception.

☐ I am willing to participate in the Achievement Test.

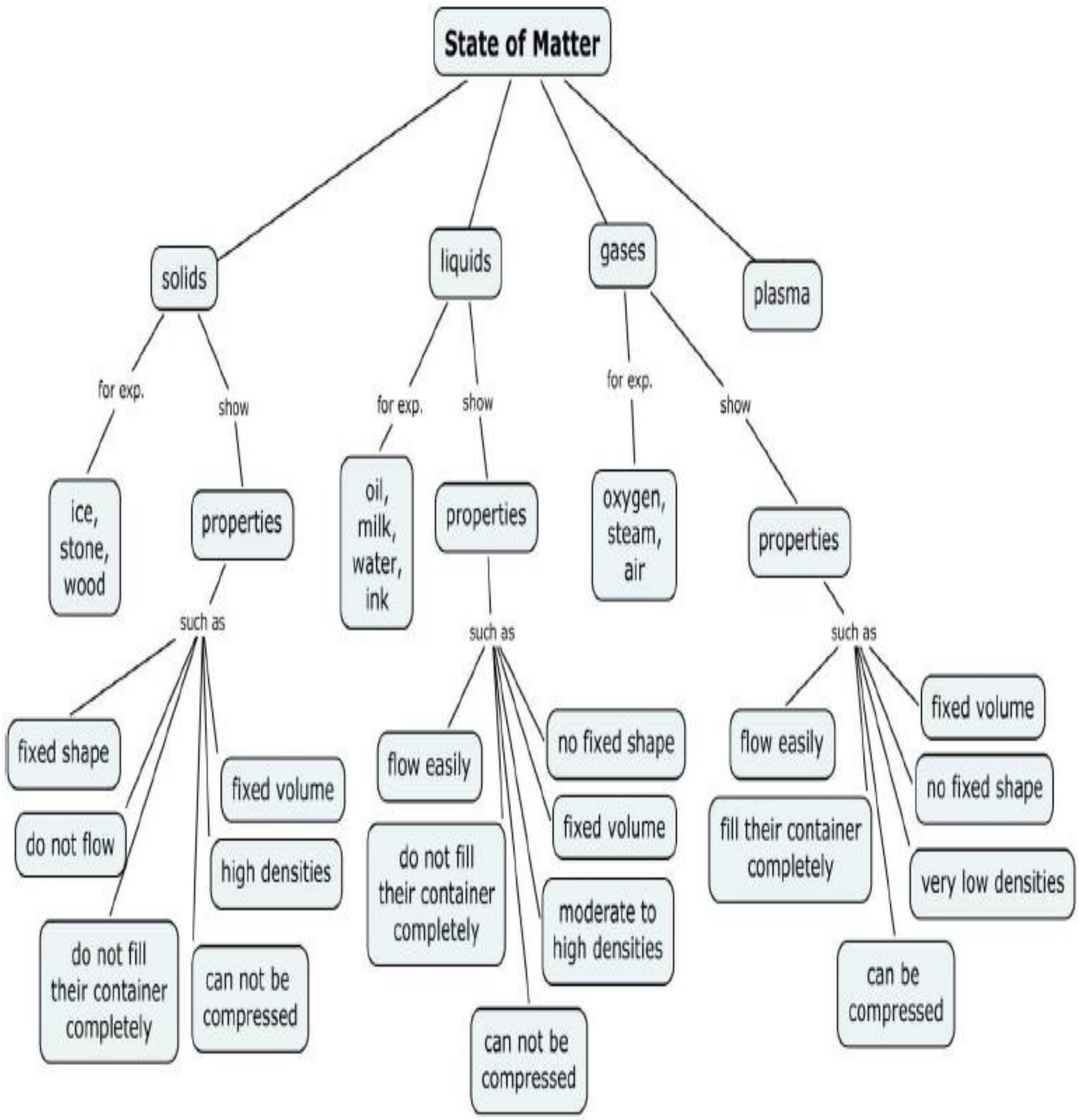
Name: ______________________________________

Signature: _________________________________ Date: _________________

Appendix: 4

Some Concept Maps Used to Teach Contents of the Topic: Matter

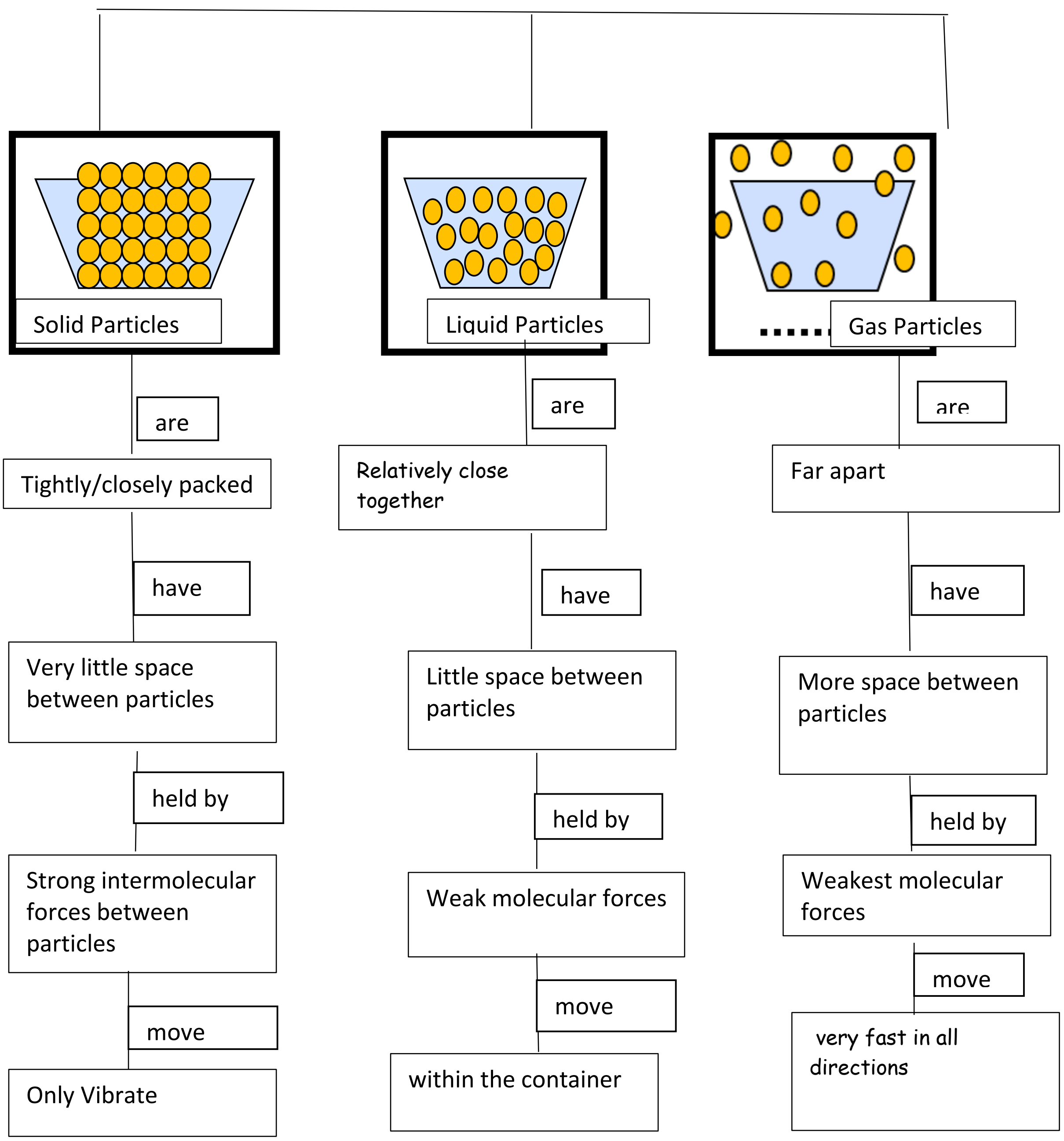
1. **Learning Objective**: To classify physical states of matter and outline their physical properties



Reference: Kiliç & Çakmak (2013).

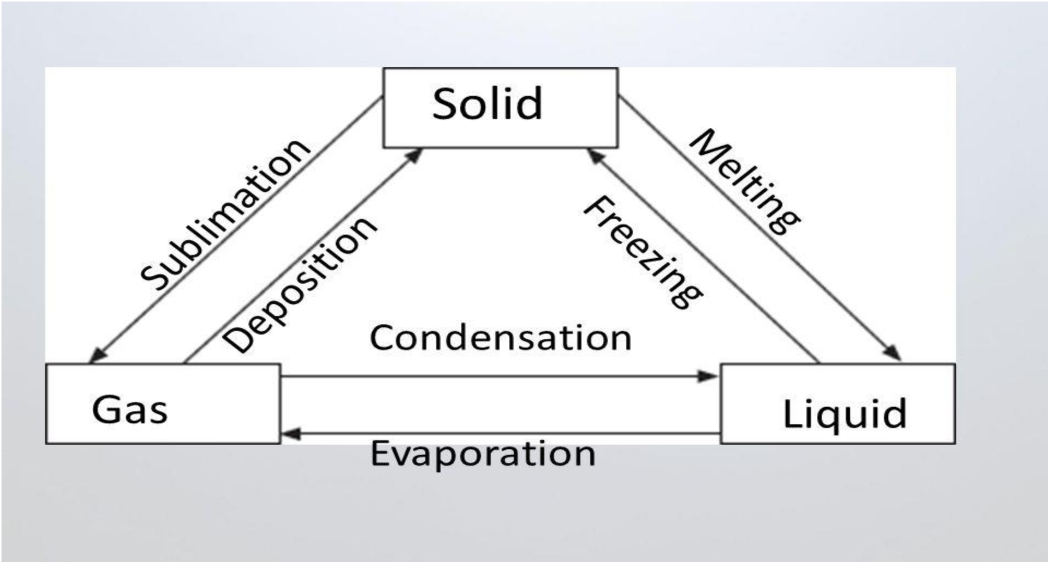
2. Learning Objective: To explain the physical properties of solids, liquids and gases using particle theory

Particle Theory

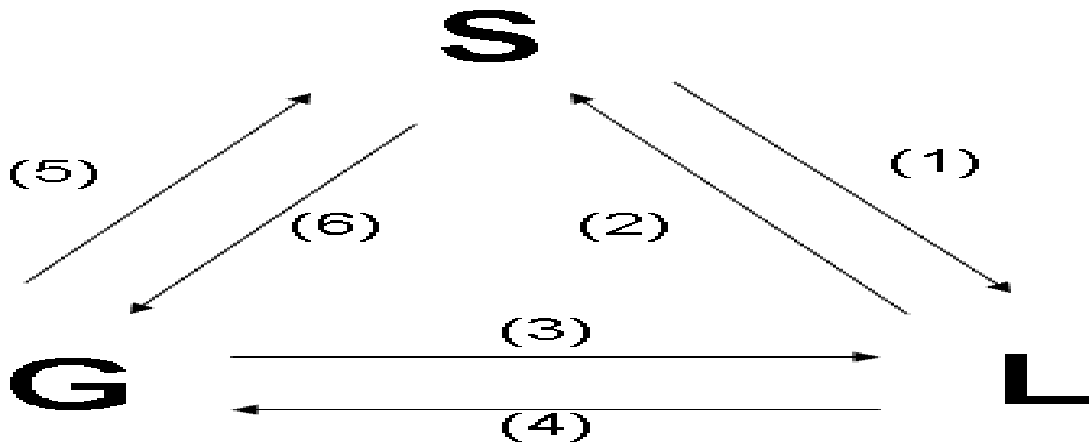


Reference : Modified version (www.tes.co.uk)

3. **Learning Objective: To explain the change of states of matter and identify the energy change**



Reference: http://slideplayer.com/slide/2387408/

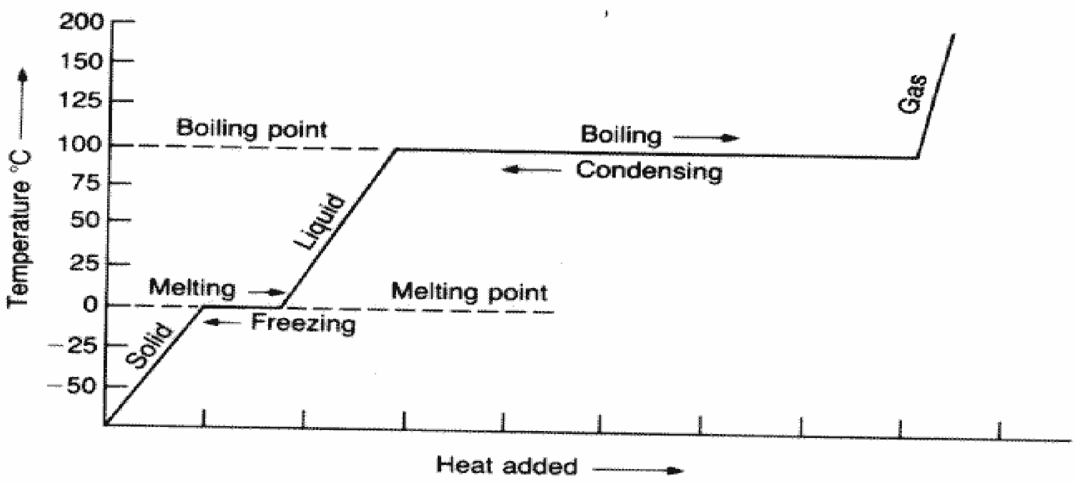


1) Melting: energy absorbed
(2) Freezing: energy released
(3) Condensation: energy released
(4) Vaporization: energy absorbed
(5) Deposition: energy released
(6) Sublimation: energy absorbed

Reference: http://www.kmacgill.com/lecture_notes/lecture_notes_14.htm

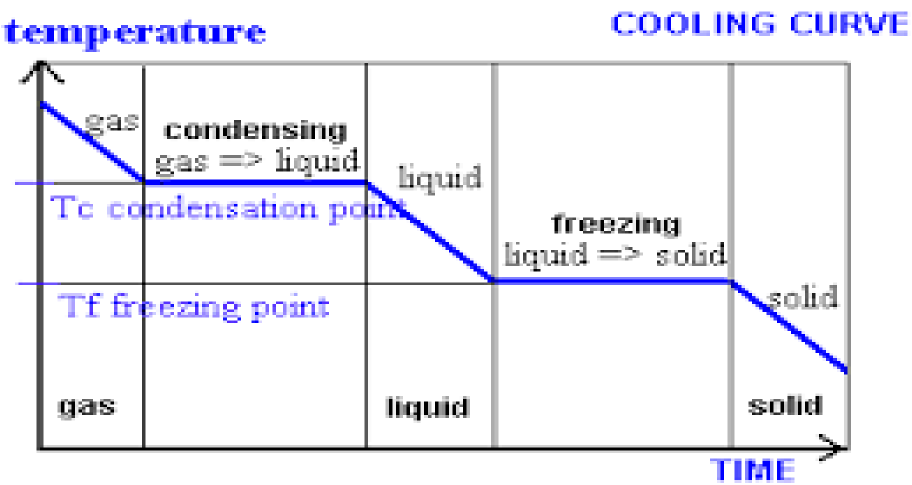
4. **Learning Objective: To Analyse and Evaluate Heating and Cooling Curves using the concept map of state changes**

Heating curve



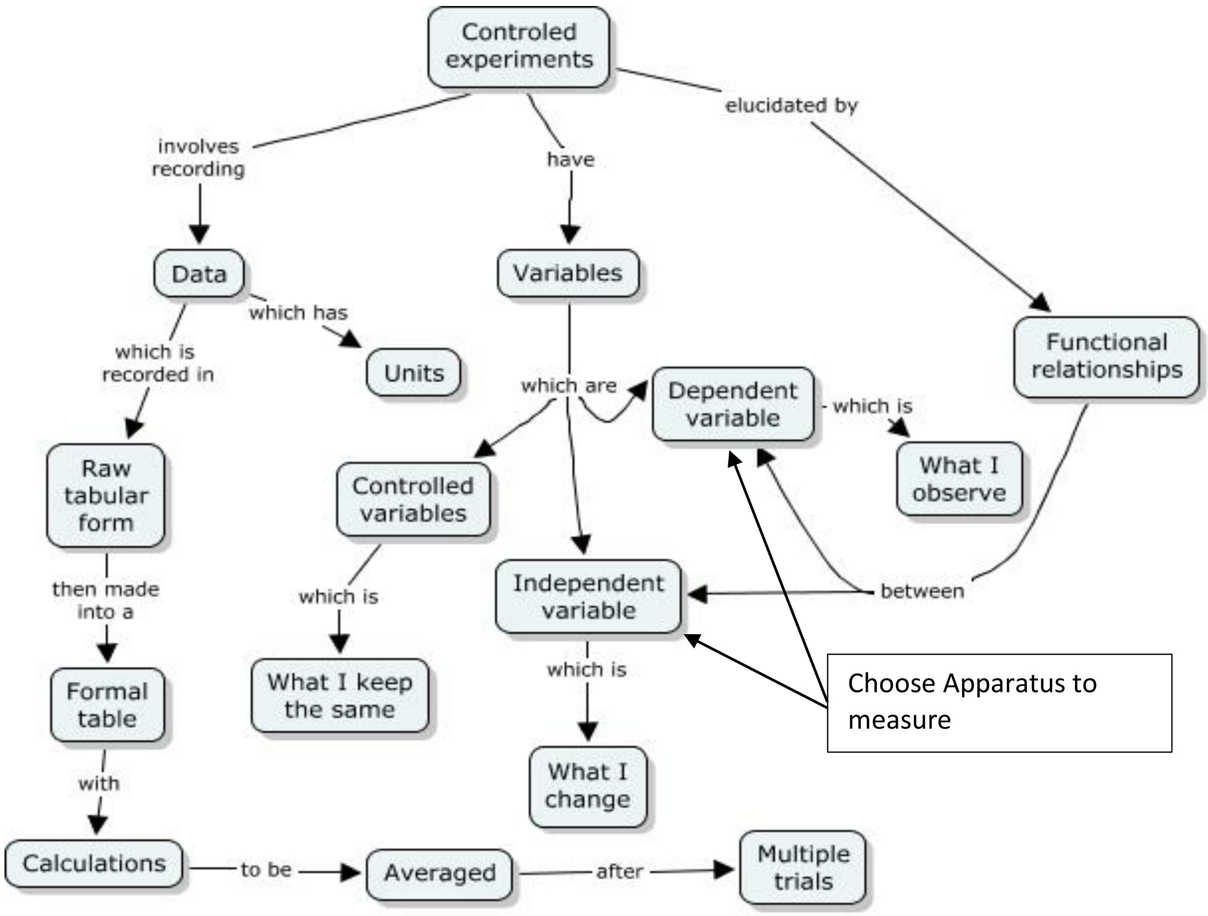
Reference: http://pudap.com/kinetic-heating/

Cooling Curve

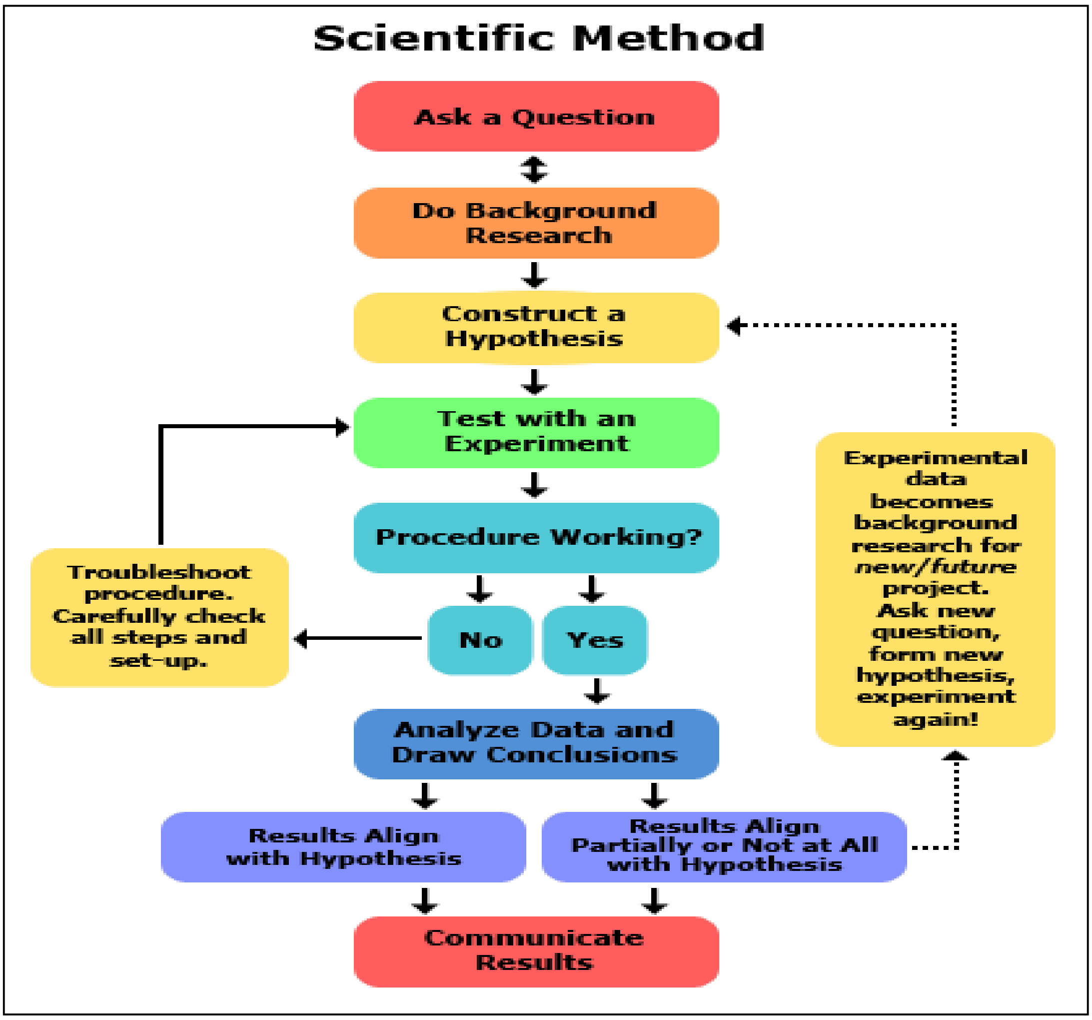


Reference: https://socratic.org/questions/why-does-water-s-phase-diagram-have-a-negative-slope

5. Learning Objective: Outline plans to design and carry out investigations, considering the variables to control, change or observe.

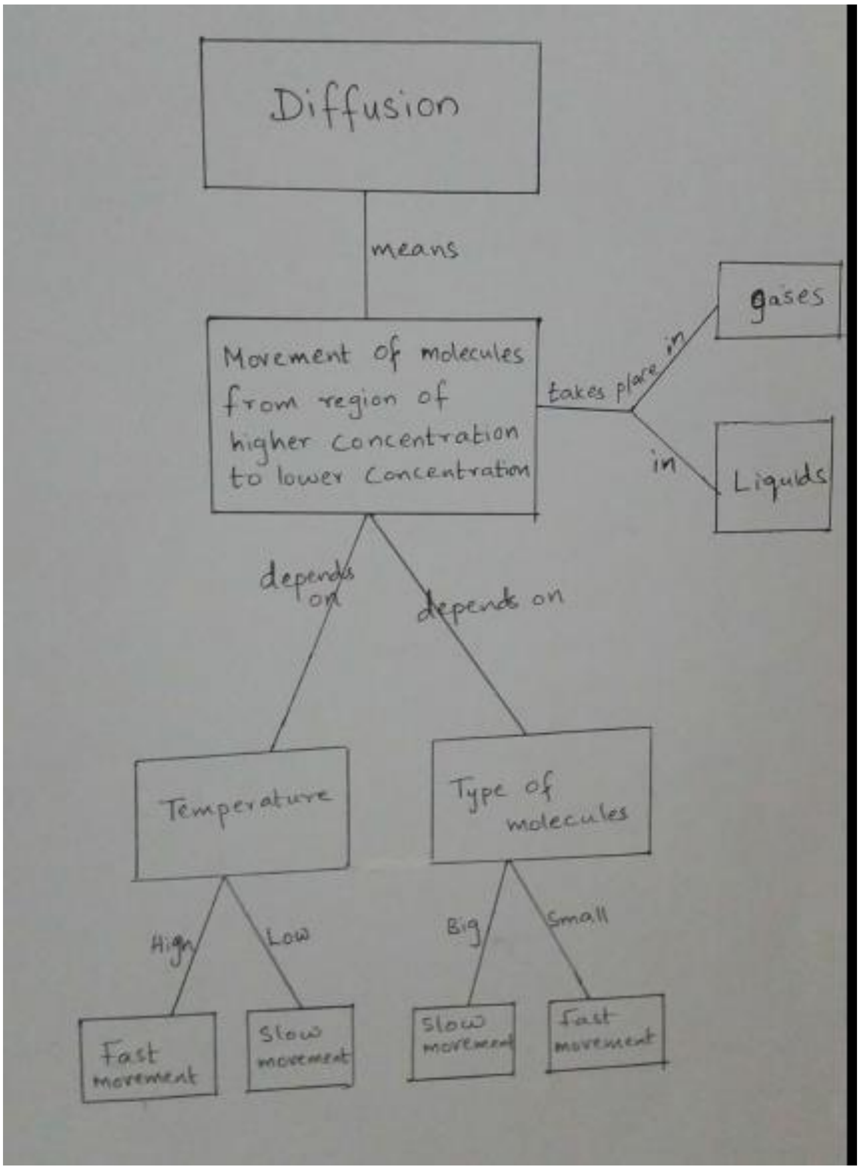


Reference: http://cmapspublic3.ihmc.us/rid=1JSK7SD1P-1J7FBY R9D/1%20Controlled%20Experiments.cmap

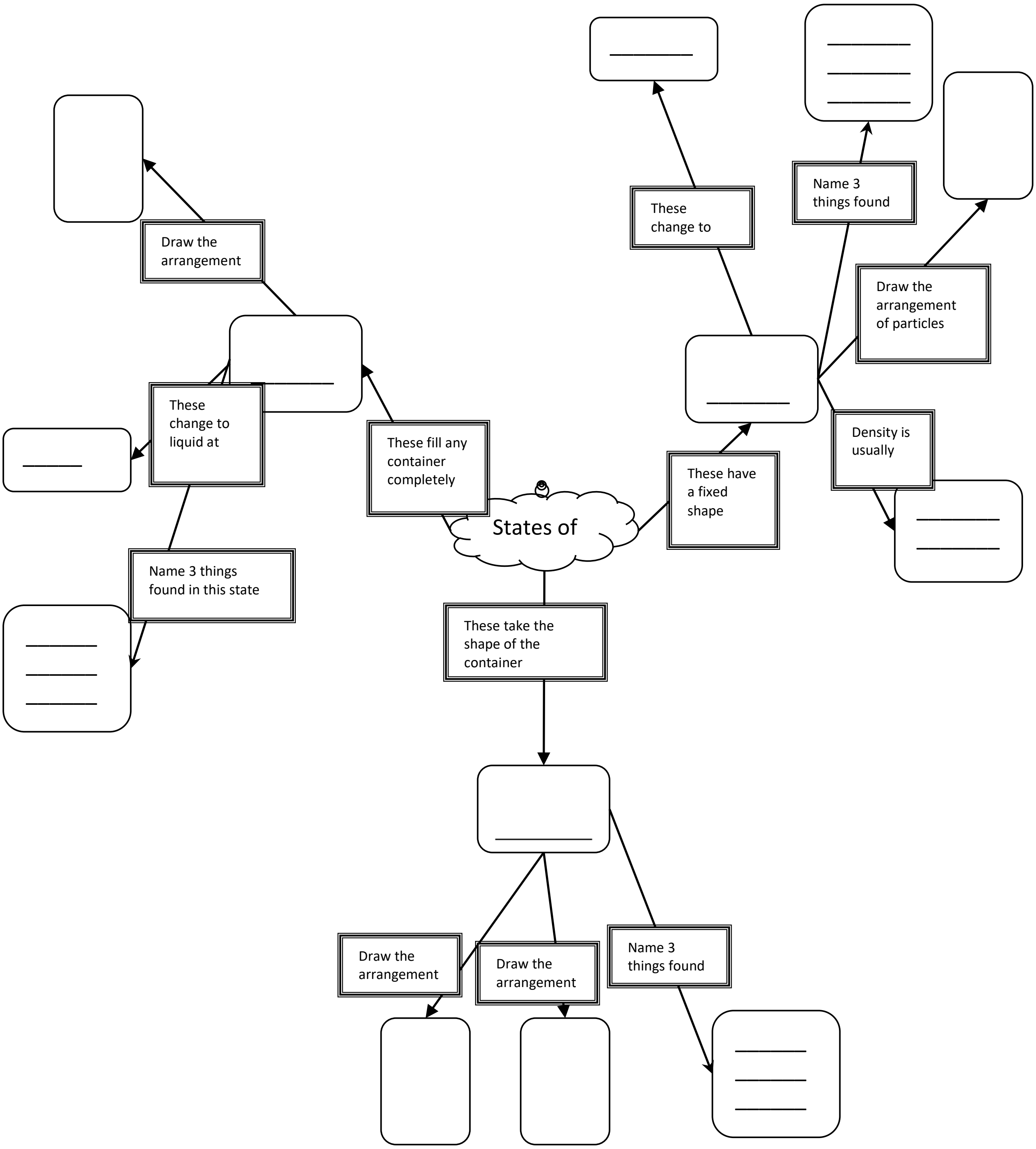


Reference: (www.ScienceBuddies.org)

6. Learning objective: To understand the process of diffusion



Activity Concept Map- Review of Matter



Reference: www.tes.co.uk

Appendix 5: CMAT (Instrument) and Marking Scheme

Chemistry Matter Achievement Test (CMAT)

Grade 7
Unit: States of Matter

Section A
There are six questions each with four possible answers A, B, C and D.

Choose the one you consider correct and circle your choice on the paper.

(1x6 =6)

1. Something that fills up all of a container and that we cannot see is a __________.

A. Solid

B. Liquid

C. Gas

D. All of the above

2. Which of the following is the opposite of boiling?

A. Evaporating

B. Freezing

C. Condensing

D. Melting

3. Which of the following statements best describe the arrangement of particles in solid?

A. Very far apart and moving quickly

B. Close together and stationary

C. Far apart and moving slowly

D. Close together and vibrating

4. Which of the following is true as a gas is changing to a liquid in condensation?

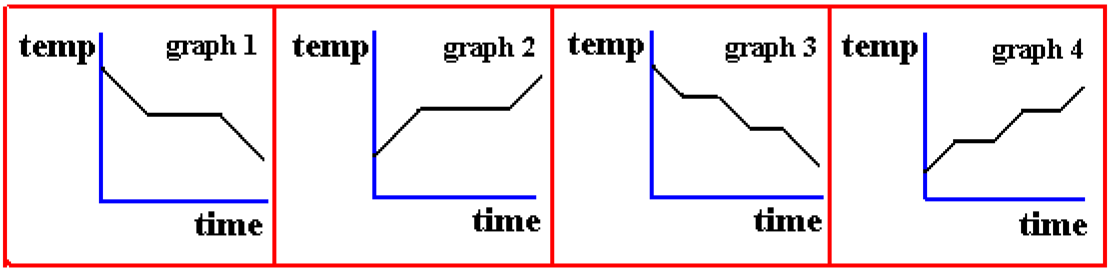
A. Energy is given out

B. Temperature increases

C. Particles gain energy

D. Particles spread apart

5. Analyze the following graphs that relates temperature and change of states.



Which graph represents how the temperature of gas varies as it eventually becomes a solid?

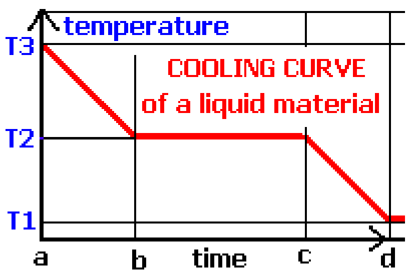
A. Graph 1

B. Graph 2

C. Graph 3

D. Graph 4

6. The graph shows the results of monitoring a hot liquid pure wax as it slowly cooled to room temperature. Which of the following can you **deduce from the results**?



A. from time a to b, the wax is starting to freeze

B. from time b to c, the wax is all liquid

C. from time c to d, the remaining liquid wax freezes

D. the freezing point of the wax is temperature T2

Section B

7. Amul and Jiao want to compare how long it takes to melt margarine and butter. They want to plan a fair test.

Which of these actions should they take? You can choose more than once. (Tick the appropriate boxes)

☐ Put equal amounts of butter and margarine in a pan and a pot.

☐ Put equal amounts of butter and margarine in two identical pans.

☐ Heat both pans one after the other on the same stove.

☐ Heat each pan on an identical stove, starting at the same time.

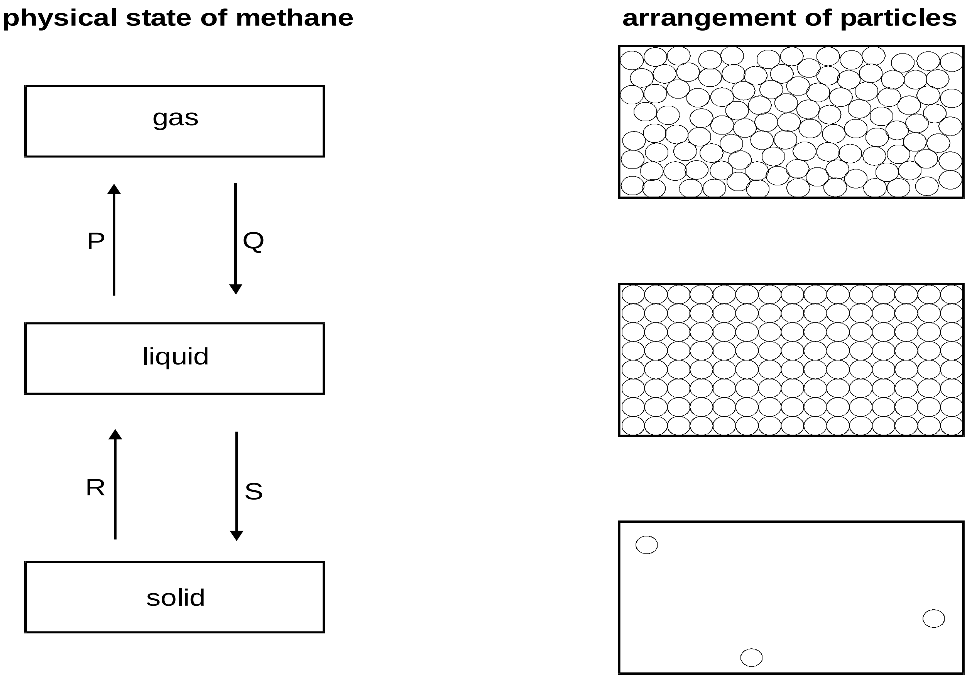
☐ Heat one pan on a gas ring and the other pan on an electric plate starting at the same time.

(2)

8. Methane can be a gas, a liquid or a solid. In the diagram below, arrows P, Q, R and S represent changes of state.

The boxes on the right show the arrangement of particles of methane in the three different physical states.

Each circle represents a particle of methane.



(a) Draw a line from each physical state of methane to the arrangement of particles in that physical state. Draw only **three** line. (1)

(b) Arrows P, Q, R and S represent changes of state. Which arrow represents:

Boiling..

(1)

(c) Liquids can only be compressed a little bit but air has maximum compressibility. Compare the compressibility of liquids and air using your understanding of particle nature of matter.

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………… (2)

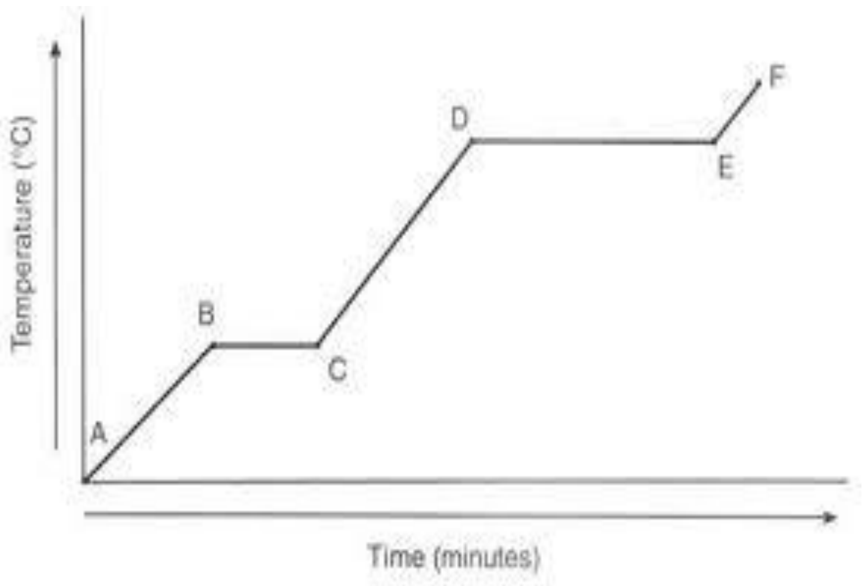
(d) Liquids are able to flow, while solids are not. What information would you use to support the view?

………………………………………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………
(2)

9. Sam is doing an experiment to find the melting point and boiling point of pure water. He measured the temperature of ice as it was heated from -5ºC to 100ºC. The graph given below is plotted using his recorded data.



a) What happens at the stage B---C?

…………………………………………………….
(1)

b) What state is the water at point F?

…………………………………………………….
(1)

(c) Explain why there curve is flat at B-C and D-E?

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………………

(1)

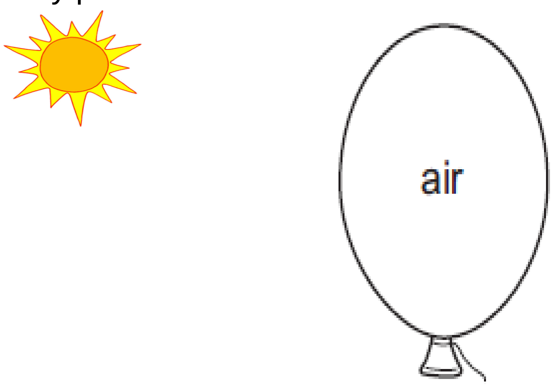
(d) The melting points and boiling points of the four elements are shown in the table.

Complete the table to give the physical states, **solid**, **liquid** or **gas**, of each element at room temperature, 21°C.

element	**Melting point in °C**	**Boiling point in °C**	**physical state at room temperature, 21°C**
bromine	–7	59	
fluorine	–220	–188	

(2)

10. Sunny wants to find the effect of heat on the air inside a balloon. As a part of the investigation he is planning to leave the balloon in a sunny place.



(a) Predict any two effects of sun's heat on the air particles inside the balloon.

……………………………………………………………………………………

……………………………………………………………………………………(2)

(b) Predict one way in which the balloon would change when it is left in a sunny place.

…………………………………………………………………………………

…………………………………………………………………………………

(1)

11. Anna brought a new liquid deodorant to the class. The temperature of the classroom was at 18^oC. She sprayed the liquid deodorant on her hands.
After a few minutes, her skin had dried.
At the same time the fragrance of the deodorant got spread all over the room. Anna called this process of diffusion.
Anna says that diffusion happens really quickly. Do you agree with this statement? Justify your answer.

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(2)

12. a) Compare and contrast boiling and evaporation.

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…………………………………………………………………………………

…………………………………………………………………………………

(2)

b) Why are we able to sip hot tea faster from saucer rather than from a cup?

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

(1)

c) Do we sweat more on a dry day or a humid day? Justify your answer

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

(1)

13. Sarah and Jim were asked by their science teacher to plan and set up an experiment to investigate the rate of diffusion of ink in water at different temperatures.

(a)Design a method including dependent, independent and controlled variables for this investigation. You may draw a concept map to show your design.

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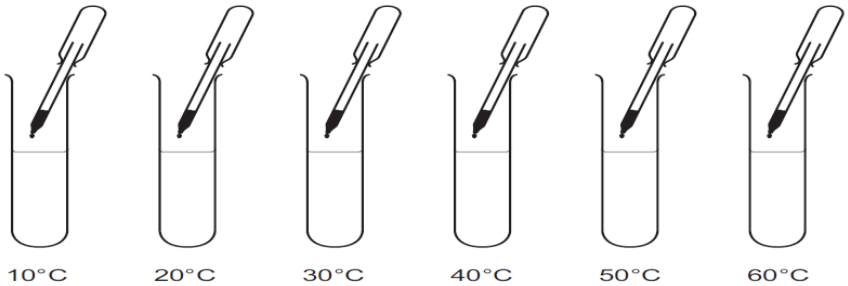
(3)

(b)Suggest one equipment Sarah and Jim would use to measure the independent variable?

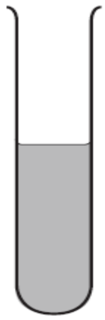
………………………………………………………………………………

(1)

Sarah and Jim have decided to use this apparatus to carry out this experiment.



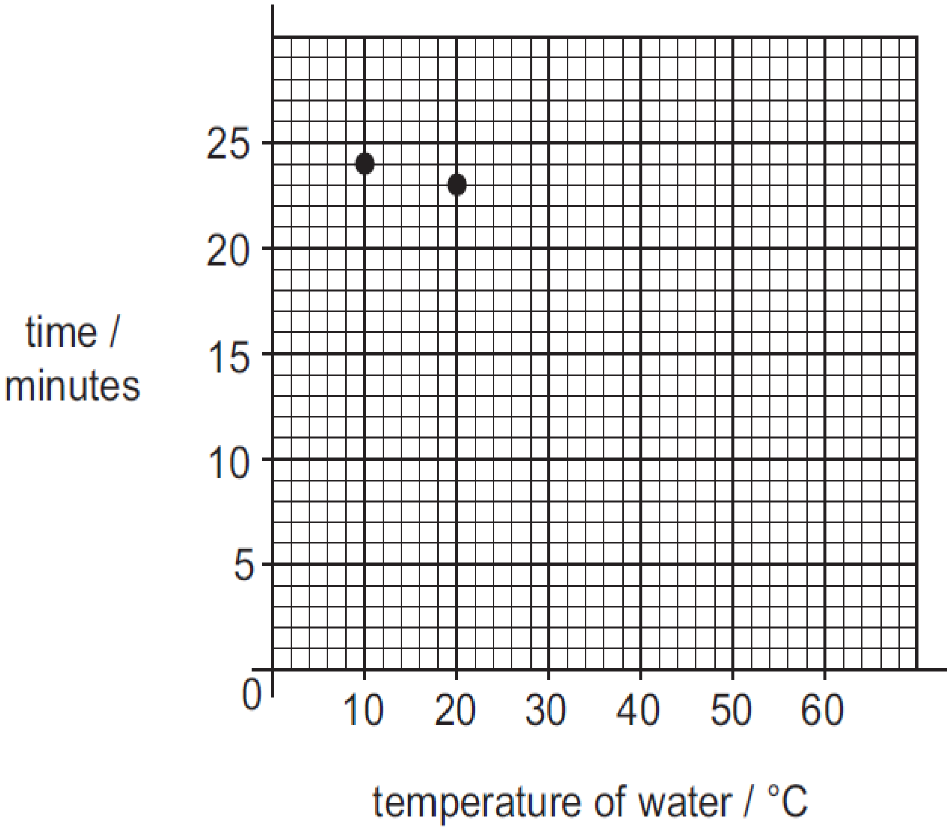
They record the time it takes for the ink in each tube to diffuse evenly.



Here are their results

temperature of water in °C	time taken to diffuse in minutes
10	24
20	23
30	16
40	12
50	8
60	4

They draw a graph based on their data



(c) Finish plotting the graph using their results and draw the best straight line through the correct points.
(1)

(d) Sarah and Jim think that the result for one temperature is wrong.

The wrong result is at _____________ °C.

Explain your answer

………………………………………………………………………………

………………………………………………………………………………

………………………………………………………………………………

(1)

(e) Sarah and Jim noticed from their results that it took only 4 minutes for the ink to diffuse at 60°C.
Evaluate the result by explaining the effect of temperature on the ink diffusion.

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(1)

End of the Test

Appendix - 6

Marking Scheme – CMAT

Q	Answer	Marks
1	C	1
2	C	1
3	D	1
4	A	1
5	C	1
6	C	1
7	*Tick two boxes (Each one carries 1 mark)* Put equal amounts of butter and margarine in two identical pans. Heat each pan on an identical stove, starting at the same time.	1 1
8	a) Draw three correct lines from each physical state to arrangement of particles *All lines correct = 1 mark* *No marks for partially completed answers*	1
	b) P	1
	c) Air particles have more spaces between them to be compressed easily (1) Liquid particles have less spaces between them (1) *(Full marks if both the concepts are correct)*	2
	d) In solids particles are held together by strong attractive forces. (1) In liquids, particles are held together by weak attractive forces. (1) *(Full marks if both the concepts are correct)*	2
9	a) Melting/ solid changes to liquid	1

	b) Gas	1
	c) During the change in states, the temperature remains constant (same).	1
	d) Liquid (1 mark) Gas (1 mark)	2
10	a) Air particles will get more energy (1 mark) Air particles will move faster (1 mark) Or They will expand or spread apart *(Any two answers)*	2
	b) Expand or increase volume or increase size or blast (1 mark)	1
11	No. Rate of diffusion increases with temperature (1 mark). The Classroom is only 18°C lower than room temperature. So diffusion will take place slowly (1 mark).	2
12	a) Boiling takes place at a specific temperature and evaporation takes place at a lower temperature than boiling point or In boiling particles changes state from all over the liquid and in evaporation particles at the surface changes state. (1 mark) (any one) In both heat is needed/ in both liquid changes to gas (1 mark) (anyone)	2
	b) Saucer has more surface area than a cup (half mark) which makes the spreading of heat faster (half mark)	1

	c) We sweat more on a humid day because sweat does not evaporate quickly as in a dry day due to enough water vapor in it.	1
13	a) Time taken for the ink to evenly spread in water(dependent)- (*1 mark)* is measured by changing temperatures (Independent variable) (*1mark)* by keeping the amount of ink, amount of water and type of ink same (Controlled Variables).	3
	b) Thermometer	1
	c) Plotting the points correctly (half mark) and drawing the best straight line through the correct points (full mark) *No marks for only drawing the line without plotting the points*	1
	d) 23 (half mark), because it doesn't fit the pattern (half mark)	1
	e) As the temperature increases, rate of diffusion increases	1
Total		35