UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENT OF SCIENCE EDUCATION

USING THE 5E MODEL TO ENHANCE THE UNDERSTANDING OF THE CONCEPTS OF DIFFUSION AND OSMOSIS IN SENIOR HIGH SCHOOLS: A CASE STUDY IN ST. FIDELIS SENIOR HIGH SCHOOL, TEASE, KWAHU AFRAM PLAINS SOUTH DISTRICT

PAUL OSEI

2014

UNIVERSITY OF EDUCATION, WINNEBA

USING THE 5E MODEL TO ENHANCE THE UNDERSTANDING OF THE CONCEPTS OF DIFFUSION AND OSMOSIS IN SENIOR HIGH SCHOOLS: A CASE STUDY IN ST. FIDELIS SENIOR HIGH SCHOOL, TEASE, KWAHU AFRAM PLAINS SOUTH DISTRICT

PAUL OSEI

(7120130005)

A dissertation in the Department of Science Education, Faculty of Science Education, submitted to the School of Graduate Studies, University of Education, Winneba in partial fulfillment of the requirement for the award of the degree of Master of Science Education

JULY, 2014

DECLARATION

Candidate's Declaration

I, PAULOSEI, declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and acknowledged is entirely the result of my own original work, and it has not been submitted in part or whole for another degree in this university or elsewhere.

----------------------------------- -----------------------------------

Paul Osei Date

Supervisors' Declaration

I hereby declare that the preparation and presentation of this dissertation was supervised in accordance with the guidelines on supervision of dissertation laid down by the University of Education, Winneba.

----------------------------------- -----------------------------------

Dr. E. K. Oppong Date

(Supervisor)

DEDICATION

Dedicated to my family, especially my mother, Rose Kumah, friends, advisors, and mentors.

ACKNOWLEDGEMENTS

The completion of this project is due to the knowledge, support, and creativity of many people. Dr. E. K. Oppong, has provided hours of service to this project by critiquing my work and offering areas of improvement. My advisor's encouragement and willingness to engage in my research interest have played a significant role in the growth of my interest in educational research.

My appreciation goes to my brother Cpl Sydney Sakujo and friend Mr. Joachim Abungba for their timely and prompt support.

I also acknowledge Mr. Mathias Attimah, current headmaster, and Fr. Foster Asiamah, former acting headmaster of St. Fidelis Senior High School for their encouragement and consent to pursue this programme. I also thank my colleague staff members and students of St. Fidelis Senior High School who assisted me and participated voluntarily in carrying out this research.

I am also grateful to my colleague course mates who supported me in diverse ways during the entire period of the course work, especially Mr. Boni Nixon and Mrs. Esther Nuertey.

TABLE OF CONTENTS

Title **Page**

LIST OF TABLES

Title **Page**

LIST OF FIGURES

Title **Page**

ABSTRACT

This study compared the effectiveness of 5E learning cycle model based on constructivist theory approach over traditionally designed instruction on second year students of St. Fidelis Senior High School understanding of the concepts of diffusion and osmosis. Two classes were randomly selected for the study; 32 students in the control group received the traditional instruction, while another 32 students in the experimental group received the 5E Model of instruction. Test scores and Inquiry-Based Instruction Questionnaire were analysed quantitatively and qualitatively. One-way ANOVA was used to analyse students test scores. This indicate significant differences between pre-test and post-test ($p < 0.05$) for both 5E method of instruction and the traditional method of instruction suggesting an improvement in students' understanding of diffusion and osmosis after treatment. The results from the one-way ANOVA showed that there was ($p < 0.05$) significant difference between the mean of post-test scores of the 5E model of instruction and the post-test means traditional method of instruction ($p < 0.05$). This suggests that the use of 5E model would lead to higher student achievement. Both quantitative and qualitative analyses suggested that the teaching activities promoted students' conceptual understanding. However, some of the students still held some misconceptions after the 5E model of instruction. In addition, most students appeared to have had very good attitudes toward using it in the science lessons suggesting that the 5E model instructional model motivates students to learn integrated science.

CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter presents the background to the study, including the statement of the problem, the purpose of the study, and the research questions addressed by the study. In addition, it looks at the educational significance, limitations and the delimitations of the study and the organization of the study.

1.2 Background to the study

St. Fidelis Senior High School in Tease, Kwahu Afram Plains South District in the Eastern Region has about 350 students from first year to third year. The school is mixed sex school and they have opportunities to interact throughout the school day.

The aspiration of many science teachers is to improve science achievement through the use of more effective instructional strategies, promoting the active role of the learner, and promoting the facilitative role of the teacher. Thus, effective teachers use a diversity of methods and approaches to assist their students in the learning process. The common teaching methods preferred by science teachers are the lecture method and question-and-answer approach (Mohapatra, 2013).

The guiding principle and major motivating factor that spur many teachers to join the teaching profession is their desire to impart knowledge to students. However, they soon realize that the resources and materials needed to achieve their aims are non-existent. The ideal situation should be that teachers should rather be innovative in their teaching approaches in harnessing resources and materials for their lessons.

The West African Senior School Certificate Examination 2013 results for St. Fidelis Senior High School showed that 31 out of 217 candidates, representing 14.29%, presented had between grades C4 and C6 in integrated science, with the best being C4. This is not surprising since most of the students do not have interest in the subject. This is expressed by students lukewarm attitude to the subject during lessons.

One possible reason for student lukewarm attitudes toward integrated science may be a shortage of well-qualified science teachers capable of providing a positive experience. Moreover, many science teachers are required to teach science outside their own subject areas. This undermines their confidence, leading them to offer a significantly more closed and less stimulating experience. Students usually complain that school science consisted of too much repetition and too much copying and note taking. They are not given enough opportunity and time to discuss any of the ideas or their implications. There is very strong empirical evidence that some of the fundamental concepts on which scientific understanding is built are commonly misunderstood by learners, and that there are patterns in the difficulties that they experience (Wang & Schmidt, 2001).

The concepts of osmosis and diffusion are fundamental to mastering many topics in chemistry and biology. The students will have a relatively easy and better understanding of more advanced topics, if they have a good grasp of the forces that lead to these phenomena and the resulting consequences. It is rather unfortunate that many senior high school teachers do not devote much instructional time on these concepts. This, inevitably, leaves students with only basic understanding of these fundamental forces. Since they play a crucial role in the study of science, it is important that students have an unambiguous understanding of the concepts and how they relate to real world situations. It is against this background that this research is undertaken to find out whether the use of 5E model can have influence on the teaching and learning of integrated science in senior high schools.

1.3 Statement of the problem

Science education researchers have established that students' misconceptions in science are very persistent and that traditional instruction is not very effective in promoting conceptual understanding (Driver, Guesne, & Tiberghien, 1985; Wandersee, Mintzes, & Novak, 1994).

The concepts of diffusion and osmosis are important in science. Many integrated science teachers at the senior high school level more often than not run through these topics. This leads to a little understanding for the students. Students are simply expected to memorize the definitions of these terms. According to Bloom's Taxonomy, memorization ranks low as such there is not a high level of understanding by the students. The likelihood of such students forgetting these definitions and terms is very high. West African Examinations Council (WAEC) Chief Examiners Report (2008) encourages teachers to shift emphasis from knowledge to comprehension and application in instructional delivery.

As a student advances, the pursuit of further knowledge, these ideas become very relevant in the students understanding of many concepts in integrated science. Because students do not receive adequate education in these areas, it is often hard for students to truly grasp the reasoning behind the phenomena learned in later courses (Patel, 2012).

1.4 Purpose of the study

A promising model of understanding to promote student understanding of science is the 5E model. This is evident by several recent science education studies that have used constructivist 5E Model in varying contexts using a variety of science topics. (Aydede Kesercіog, & Arabacıog, 2010; Bryce & Macmillan, 2005).

The main purpose of this study was to compare the effectiveness of the 5E learning cycle model based on the constructivist theory approach over traditionally designed instruction on second year students of St. Fidelis Senior High School understanding of diffusion and osmosis concepts.

1.5 Research Questions

The following research questions guided the study.

1. What is the effect of the 5E model on second year students St. Fidelis Senior High School of understanding of the concept of diffusion and osmosis?
2. What are some of the misconceptions held by second year students of St. Fidelis Senior High School about diffusion and osmosis?
3. Will the use of the 5E instructional model bring any change in the attitude of second year students in St. Fidelis Senior School toward science?

1.6 Research Objectives

The study seeks to:

1. To study the effect of the 5E model on understanding of the concept of diffusion and osmosis of second year students of St. Fidelis Senior High School.

2. Identify some misconceptions held by second year students of St. Fidelis Senior High School about diffusion and osmosis.

3. Determine the effectiveness of the 5E model of instruction in improving second year students attitudes towards teaching and learning of integrated science.

1.7 Null Hypothesis

To further guide this study, the following null hypotheses were stated and tested at 0.05 level of significance.

Ho1: There is no significant difference in the mean gain achievement pre-test scores between students taught with 5E model and traditional method.

Ho2: There is no significant difference in the mean gain achievement of pre-test scores and post-test scores of students taught by the traditional method.

Ho3: There is no significant difference in the mean gain achievement of pre-test scores and post-test scores of students taught using 5E model method.

Ho4: There is no significant difference in the mean gain achievement post-test scores between students taught using 5E model and traditional method.

1.8 Significance of the study

It is hoped that the outcome of the research would enable teachers and administrators improve students' interest and understanding of the concept of diffusion and osmosis, in particular, and science in general in St. Fidelis Senior High School Tease. Consequently, its adoption to foster teaching and learning of integrated science.

This study would also serve as a source of reference for those who wish to carry out research into similar issues on how well science is taught and learnt in schools.

1.9 Delimitations of the Study

The scope was narrowed due to the rather short time frame that the study was carried out. In the study the intervention stage, the lessons were delayed because the researcher who doubles as the teacher had to liaise with the teacher who handles the second year class.

This study was limited to only SHS 2 students, since they have had adequate exposure to concepts in science and were not under any examination pressure and, therefore, expected to be in a better position to take part in the study.

1.10 Limitations of the Study

The study should have been conducted in other Senior High Schools in the District. However, the study was narrowed down in scope. Due to time frame and financial constraints, the study was limited to only St. Fidelis Senior High School Kwahu Afram Plains South District of the Eastern Region.

1.11 Organisation of the Study

This study is presented in five chapters. The first chapter deals with the background to the study, statement of the problem, purpose of the study, research questions, significance of the study, delimitation of the study, limitation of the study, and organization of the study. In Chapter Two, literature that is relevant to the research was reviewed. Chapter Three discusses the research design, population and sample and the sampling procedures, the research instrument for collecting the data, the method of data collection and data analysis. Chapter Four, deals with the results and discussion. Chapter Five discusses the findings and looks at summary of findings, conclusions, recommendations and suggestions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter discusses the literature related to the subject under study. The following is the outline for the literature review:

a) Theoretical framework,
b) why we educate for understanding,
c) traditional instructional method,
d) constructivism,
e) inquiry and the learning cycle,
f) 5E learning model as a scientific pedagogy,
g) concept of diffusion and osmosis,
h) misconceptions,
i) attitude of students towards learning.

2.2 Theoretical framework

This research has its theoretical basis on the constructivist learning theory. Constructivist teaching is based on the constructivist learning theory. Constructivism in science education is based upon a philosophy that all learning is constructed and that new knowledge is built upon the prior experiences of the learner (Naylor, 1999; Kruckeberg, 2006). The foundation of constructivism is attributed to the work of Dewey, Piaget and Vygotsky, who argue that how students respond to new learning situations is influenced by their prior knowledge (Hyslop-Margison & Strobel, 2011). This philosophy has influenced a change in science curriculum and instruction to take into account students' experiences. Fox (2001) asserts that the foundation of constructivism is based upon the idea that learning is not passively absorbed. It is an active process in which knowledge is both invented and personal to the learner. The key for learning is fundamentally linked to the active participation of the learner. New knowledge can only be constructed by linking meaning to the learner's previous, existing knowledge (Naylor, 1999).

Constructivism also gives teachers another angle to look at how students learn and to focus on processes and provides suitable ways of documenting change and transformation. It also serves as a reminder to teachers to look for different ways of engaging individual students, develop rich environment for exploration, prepare coherent problem sets and challenges that focus the model building effort, elicit and communicate students perceptions and interpretations(Abdal-Haqq, 1998)

Ultanir (2012) argues that some aspects of the pedagogy of Dewey, Piaget and Montessori share some commonality in regards to the knowledge learning process of a child. Each of them agrees that the acquisition of knowledge and learning is about constructing meaning as opposed to passive reception. An individual's process of developing new knowledge is affected by previously acquired knowledge.

Constructivists again maintain that individuals construct or create their own new understandings or knowledge through the interaction of what they already know and believe and the ideas, events, and the activities with which they come into contact (Richardson, 1997). The settings of a constructivist learning environment is characterized by, engagement, inquiry, problem-solving, and collaboration with others. The teacher in such an environment serves as a guide, facilitator, and co-explorer who encourage learners to question challenge, formulate their own ideas, opinions, and conclusions de-emphasizing “correct” answers and single interpretations (Ismat, 1998).

Several publications cite the importance of teachers' modeling constructivist approaches that engage students in interdisciplinary exploration, collaborative activity, and field-based opportunities for experiential learning, reflection, and self-examination (Kaufman, 1996;Kroll & LaBosky, 1996) if future teachers are to be able to employ these strategies in schools.

Piaget (1970) suggests that learning occurs through the construction of meaning rather than through passive reception. According to Piaget, when a student is confronted with new information, he performs the functions of assimilation and adaptation. He compares this information with knowledge that already exists in his mind. If the old information does not conform to the new, he reorganizes his mind with respect to the new information. Thus a learner’s cognitive development can be said to be a continuous effort.

2.3 Why Educate for Understanding?

The ultimate goal of science education is that we want to improve students’ knowledge and understanding of scientific concepts. The question is why should we pursue understanding? Perkins (1993) argues that knowledge and skill themselves does not guarantee understanding and that people can acquire knowledge and routine skills without understanding their basis or when to use them. Therefore, knowledge and skills that are not understood do students little good.

Additionally, the goal of science education has always been to prepare individuals who would develop a certain level of scientific understanding after their formal education in school. These scientifically literate individuals would be capable of applying their knowledge and skills acquired in science, whenever personal or socially relevant issues demanded such understanding. For instance, by having an understanding of science contents such as Physiology, Biology and Chemistry, scientifically literate individuals would be able to use reasons to form their opinions and draw valid individual inferences about such health-related issues such as nutritional awareness and medicine usage, rather than being misled or duped by propaganda or positions not supported by evidence (Wang & Schmidt, 2001).

In the long term, education must aim for active use of knowledge and skill (Perkins, 1992). Students acquire knowledge and skills in school so that they can put it to a more practical use in various professions, such as engineers, doctors, and scientists that require appreciation, understanding and judgment.

Science concepts are important to science instruction, and students’ understanding of these concepts is crucial to successful teaching and learning. It is in this vain that Millar (1989) noted that without an understanding of science concepts it would be nearly impossible for students to follow much of the public discussion of scientific results or public issues pertaining to science and technology.

According to Johnstone (1991), science can be understood at three different levels, each increasingly difficult: the phenomena (macroscopic), the particle (microscopic), and the 'symbolic. For example, if we consider water, most two-year-old children can recognize and name the colorless, odorless liquid in a glass as water because they know the properties of the phenomenon water. A second way to understand water is to represent it as a collection of particles (molecules) that have attractive forces between them and that consists of the atomic particles hydrogen and oxygen. This mode of representation is certainly more complex than focusing on the physical properties of water. A third way of representing water is by using the symbols for hydrogen and oxygen to represent the formula. In addition, symbolic mathematical formulas can be used to show properties of water. For example, the density of water equals mass/volume or $D = M/V = 1.0$ g/mL at I atm and 4^0C. Students with a sound conceptual understanding of water integrate these three ways of representing water into long-term memory.

Perkins (1993) ponders on the query: *What is understanding? And you will realize that good answers are not obvious.* To draw a comparison, we all have a reasonable conception of what knowing is. When a student knows something, the student can bring it forth upon call and tell us the knowledge or demonstrate the skill. However, understanding something is a more subtle matter. A student might be able to recite reams of facts and demonstrate routine skills with very little understanding. Perkins (1993) sums it up that somehow, understanding goes beyond knowing; understanding something is a matter of being able to carry out a variety of "performances" concerning the topic.

One thing seems clear when it comes to understanding; even young children are likely to hold on to their own explanations (ideas) about the world despite what they are told in school. Unless students are faced with experiences that challenge their conceptions, they are not likely to change their conceptions of how things work or accept alternative descriptions as useful or important (Suping, 2003).

One factor which has contributed to low interest in science by students' hence low understanding of concepts by students is the method adopted for teaching and learning science. Fensham (2008, p. 20-21) listed four views of students which contribute directly to low interest in science:

(i) Science teaching is predominantly transmissive;

(ii) The content of school science has an abstractness that makes it irrelevant;

(iii) Learning science is relatively difficult, for both successful and unsuccessful students;

(iv) Hence, it is not surprising that many students in considering the senior secondary years asking: Why should I continue studying science subjects when there are more interactive, interesting and less difficult ones to study?

This unhealthy development in the outlook of students towards science has sparked the search for alternative methods of science teaching and learning which can stimulate students' interest in science. Science education as a field of study is, therefor,e in dire need of methods with qualities, such as lesson clarity, promotion of self-activity, promotion of self-development, stimulation of interest and curiosity, and relying on the psychological process of teaching and learning to recommend to science teachers. The methods should encourage science teaching and learning that is better than it is now.

In summary, understanding something is a matter of being able to carry out a variety of "performances" concerning the topic (Perkins, 1992).

2.4 Traditional Instructional Method

The traditional method of teaching and learning sees teachers as passing over their knowledge to their pupils (Bennett, 2003 B; Trowbridge, Bybee, & Powell, 2000). This view is strongly linked to expository teaching; teachers standing at the front telling their pupils about scientific ideas. The traditional method implies that the role played by pupils in the learning process is largely passive, and that a pupil's mind is a blank slate onto which knowledge can be written. Ajaja (2013) states the following advantages of the traditional teaching method:

1. It is easy to create interest in a topic or subject by the teacher.

2. Students easily acquire knowledge, new information, and explanation of events or things.

3. It helps students to clarify and gain better understanding of a subject, topic, matter or event.

4. Students and teachers cover more content materials within a short period of time.

The major limitation of this method is that there is relatively little student activity and involvement (Bennett, 2003; Trowbridge et al., 2000). Thus, the students are said to be passive .The limitation experienced with the transmission approach led to the development of other views of science teaching and learning.

2.5 Constructivism

Learners have diverse levels of ability which needs training and practice, as most of scientific and technological achievements of man emanate from the ideas of innovators. These hidden ideas have to be developed through training and practice.

We, therefore, need teaching and learning strategies that will provide us with a wide range and advanced educational potential that will help our students to build on their information, develop their mental abilities and train them to be innovative and novel. This can only be done by giving the students the opportunity to express, shape and test their ideas by providing them with appropriate resources, raising their interests and exciting their deep insightful thinking with the help of guided modules and various strategies and teaching methods. One of the key educational theories, the constructivist theory is interested in arousing the learner's thinking and makes him/her active, interactive and positive during the learning process.

Constructivism is defined as a set of beliefs about knowledge that begins with the assumption that reality exists but cannot be known as a set of truth (Tobin & Tippins, 1994).

Constructivists embrace the concept that learners bring their own ideas about how the world works. According to the constructivist view, "learners test new ideas against that which they already believe to be true. If the new ideas seem to fit in with their pictures of the world, they have little difficulty learning the ideas … if the new ideas don't seem to fit the learners' picture of reality then they won't seem to make sense. Learners are likely to dismiss them … or eventually accommodate the new ideas and change the way they understand the world" (Colburn 2003, p. 59). Kruckeberg (2006) indicates that if new content is not connected to students' prior experiences, it is difficult for the student to find it meaningful, which impacts their ability to assimilate the new information.

Constructivist thinking assumes that anything constructed by the learner becomes meaningful and compels the learner to a perspective about learning through the individual systems and experience and to find a relationship between the previous and the new knowledge (Gordon, 2009).

Von Glasersfeld (1993) argues that constructivism is a way of knowing that recognizes the real world as a source of knowledge. Students are expected to learn about the external world made up of objects and events. Students can however form approximations of reality, but never a true idea of it. What we can endeavour to achieve is to build useful ideas about the world that are viable and can be used to understand and explain nature. This thought implies that reality is dependent upon the mind for its existence, hence knowledge is constructed by the mind rather than being a facsimile of reality (Von Glasersfeld, 1993).

Artino (2008) indicates that literature on education confirms that learners' success is dependent on their flowing, comprehensive cognitive inventory and subsequently its good utilization and application in solving problems; thus, the learner is not static, and should acquire renewable concepts and knowledge, and should improve him/herself in order to remain continual and interactive with others, so that he/she would be able to solve his/her real problems in meaningful tasks.

The aim of a constructivist model, consequently, is to give students experiences that make them adjust their conceptions. The students will therefore be able to “redefine, reorganize, elaborate, and change their initial concepts through self-reflection and interaction with their peers and their environment” (Bybee 1997, p. 176).

Educational literature is replete with researches where constructivist approach was used; it has been shown that constructivist teaching strategies were effective in enhancing students understanding and achievement. Treagust (1996) concluded after his studies that constructivism allow for greater learning success. Active participation has been shown to lead to both greater understanding and greater interest in science. Hand, Treagust, and Vance, (1997) in the study investigated junior secondary school students perceptions of implementation of constructivist approach to the teaching of science, where students were more actively involved, had more discussions, practical work, and more fun. It was concluded that students were more active in the learning process and had opportunity to see and control their thinking as they constructed knowledge more confidently and became more confident in their understanding of science. Consequently, constructivist teaching and learning approaches led to a greater understanding of concepts. Caprio (1994) after examining the effectiveness of the constructivist approach, compared with the traditional lecture-lab method concluded that students taught by constructivist methodology seemed more confident of their learning. They had considerably better exam grades. Furthermore, Akkus, Kadayıfçı, and Atasoy, (2003) looked at the effectiveness of the instruction based on the constructivist approach by focusing on the in-class teacher student and student-student interaction within small groups over traditional method. The results indicated that students instructed by constructivist approach acquired chemical equilibrium concepts better than the students instructed by traditional method.

2.6 Models in Education

Generally, a model is a representation of a phenomenon, an object, or idea (Gilbert, 1991). In science, Tregidgo and Ratcliffe (2000) define a model as the outcome of representing an object, phenomenon or idea (the target) with a more familiar one (the source). For example, one model of the structure of an atom (target) is the arrangement of planets orbiting the Sun (source).

Models play an important role in the teaching and learning of many concepts in science. Models are an indispensable part of scientific inquiry and communication (Giere, Bickle, & Mauldin, 2006; Morgan & Morrison, 1999). Also, models are effective and essential in the production, dissemination, and acceptance of scientific knowledge (Halloun, 2007; Gilbert, 1991). They can be used to make otherwise abstract entities visible (Francoeur, 1997).

Instructional design models provide for a systematic approach of implementing the instructional design process for a specific educational initiative (Morrison, Ross & Kemp, 2004).

Instructional models can be defined as practice-oriented theories offering explicit guidance on how to help people learn that offer situation-specific methods, that in turn are described in terms of components, and that are known to be effective for learning under some conditions (to some extent). Instructional models or theories fit into an existing body of practical design knowledge ready for application. (Reigeluth, 1999).

2.7 Inquiry and the Learning Cycle

The National Science Education Standards (NSES,1996) define inquiry as:

> Inquiry is a set of interrelated processes by which scientists and students pose questions about the natural world and investigate phenomena; in doing so, students acquire knowledge and develop a rich understanding of concepts, principles, models, and theories. Inquiry is a critical component of a science program at all grade levels and in every domain of science, and designers of curricula and programs must be sure that the approach to content, as well as the teaching and assessment strategies, reflect the acquisition of scientific understanding through inquiry. Students then will learn science in a way that reflects how science actually works (p. 214).

Inquiry-based methods of teaching science focus on student-constructed learning as opposed to teacher-transmitted information. Inquiry encourages students to connect their prior knowledge to observations and to use their observations as evidence to increase personal scientific knowledge (Shields, 2006). In inquiry-based science education, children become engaged in many of the activities and thinking processes that scientists use to produce new knowledge. Bybee (2002) outlines five essential features to inquiry in the classroom, those are as follows:

1. Learners engage in scientifically orientated questions.
2. Learners give priority to evidence in responding to questions.

3. Learners formulate explanations from evidence.
4. Learners connect explanations to scientific knowledge.
5. Learners communicate and justify explanations

2.7.1 Key to Inquiry's Successful Use in the Biology Classroom

According to Uno (1990) keys to successful use of inquiry in classroom are:

1. The use of inquiry requires a good rapport between the teacher and the students. Asking open-ended questions to create a student-dominated atmosphere so that discussions prevail is key to the success of inquiry based lessons.

2. Have students use as many hands-on activities as possible to help them discover biological concepts for themselves and provide students with an introduction to a concept and enough background information.

3. It is important to incorporate elements of the scientific method as often as possible to allow the student to make observations, form hypotheses, and test their hypotheses through experimentation.

4. Before class, prepare questions which will help to steer the direction of the class, however, be flexible and allow periodic discussion. Ensure you ask only one question at a time and try to avoid yes/no questions or lower order questions as often as possible. Leave sufficient wait time to allow students to answer the questions. Do not answer your own questions: if there is no response, rephrase the question until there is one.

5. Try to involve everyone.

In contrast, the traditional classroom often looks like a one-person show with a largely uninvolved learner usually dominated by direct and one-sided instruction. Traditional approach follows the assumption that there is a fixed body of knowledge that the student must come to know. Students are expected to blindly accept the information they are given without questioning the instructor (Stofflett, 1998).

The traditional approaches seek to transfer thoughts and meanings from the teacher to the passive student leaving little opportunity for student-initiated questions, independent thinking or communication between students. Even with the activities-based subjects, activities may be done in a group but would not encourage discussion or exploration of the concepts involved. This teacher-centered method of teaching also assumes that all students have the same level of background knowledge in the subject matter and are able to absorb the material at the same pace (Lord, 1999).

In structured inquiry the student is presented with the input by the teacher to explore along with the procedures and materials. The learning cycle model is a teaching procedure consistent with the inquiry nature of science and with the way children naturally learn (Cavallo & Laubach, 2001).

Scientific inquiry is an opportunity for students to gain insights not only into science concepts and principles, but also into the ways in which scientists think and operate when they acquire knowledge about nature. Classifications of the goals for laboratory instruction clearly reflect these two aspects of practical work in science education, listing among other areas the promotion of scientific thinking and the scientific method and the development of conceptual understanding. These classifications have contributed significantly to clarifying the role of practical experimental work in science education. In addition, studies investigating the aims that teachers pursue in experiments have provided precise empirical information so that it is possible, to identify appropriate activities and experiences from all modes of instruction that will best facilitate these goals (Deka, 2010).

2.8 The 5E Model (Learning Cycle) as major scientific pedagogy

This study makes use of the 5E Model as the major pedagogical tool for the following reasons. First, 5E Model is one of the widely-adopted pedagogies as an indoor activity in the of teaching natural-science (Bybee, Taylor, Gardner, Van Scotter, Powell, Westbrook, & Lande, 2006). The 5E Model of instruction is seen as an effective hands-on, minds-on, inquiry-based scientific pedagogy, especially for enhancing understanding (Stamp & O'Brien, 2005; Bybee et al., 2006).

Learning cycle which is an inquiry- based teaching model, is useful to teachers in designing curriculum materials and instructional strategies in science. The model is derived from constructivist ideas of the nature of science, and the developmental theory of Jean Piaget (Piaget, 1970).

The 5E Model was originally proposed by Karplus as part of SCIS, the Science Curriculum Improvement Study (Atkin & Karplus, 1962; Karplus & Thier, 1967) with the underlying principle that children have an experience with the phenomena in the learning of the concept / topic. It is a teaching-and-learning procedure that is consistent with the privileged status of inquiry and with ways in which students learn naturally (Musheno & Lawson, 1999). The Learning Cycle has been used in science education from its conception. In the earlier stages, the learning cycle, as a teaching method, was made up of three stages: exploration, reaching a concept and application. However, as the objectives of science teaching developed further, learning cycle consisted now of four stages: exploration, explanation, elaboration and evaluation(Musheno & Lawson, 1999). The Biological Science Curriculum Study (BSCS), headed by Bybee in 1993, developed a constructivist study method called The 5 E Learning Cycle, which are the stages of (1) Engagement, (2) Exploration, (3) Explanation, (4) Elaboration and (5) Evaluation. The 5E learning cycle has been shown to be an extremely effective approach to learning (Lawson 1995; Guzzetti, Taylor, Glass and Gammas, 1993).

The following is explanation of these stages (David 2003; Khataybeh 2005).

2.8.1. Engagement

Engagement stage is designed to help students understand the learning task and make connections between learning experiences. It should stimulate interest and prompt students to identify their own questions about the topic. Students explore the questions raised after they gain more understanding of the topic and the tools needed to investigate the ideas. Activities in this stage include reading, posing a question, defining problem, or demonstrating a discrepant event, then using small group discussions to stimulate and share ideas. To connect science to students' lives, we frequently use historical events, such as natural disasters, to stimulate curiosity and motivate learning. Instructors help students connect previous knowledge to the new concepts introduced in the unit. Here you can uncover what students know and think about a topic as well as determine their misconceptions.

2.8.2. Exploration

In the Exploration stage students have the opportunity to get directly involved with the key concepts through guided exploration of scientific, geographic, economic, and other data sets. They have to identify patterns in the data and connecting them to Earth processes. This further should arouse student curiosity and new questions develop. Frequently, students diverge from the slated activity to explore their own questions, continually building on their knowledge base. Through this process of questioning and exploration, students would begin to formulate their understanding of the basic concepts. In this stage, instructors have to observe and listen to students as they interact with each other and the data sets. Probing questions help students clarify their understanding of major concepts and redirect their investigations when necessary. It is essential to allow adequate time at this point for students to thoroughly investigate the guiding questions in the module, as well as the questions they have generated themselves. The purpose is to provide hands-on experiences they can use later to formally introduce a concept, process or skill.

2.8.3. Explanation

In this stage, students are introduced more formally to the lesson's science concepts. Through readings and discussions, students gain understanding of the major concepts and can verify answers to questions or problems posed earlier. In addition, more abstract concepts not easily explored in earlier activities are introduced and explained. As students formulate new ideas to interpret observations made in the exploration, appropriate scientific terminology can be introduced. It is important that students' explanations are clearly connected to the experiences they had in the *engage* and *explore* phases by the teacher. If students have unresolved questions, they may continue to look for solutions in the elaborate stage.

2.8.4. Elaboration

In the elaboration stage, some students may still have misconceptions, or they may understand the concepts only in the context of the previous exploration. Elaboration activities can help students correct their remaining misconceptions and generalize the concepts in a broader context. These activities also challenge students to apply, extend, or elaborate upon concepts and skills in a different situation, resulting in deeper understanding. Providing closure to the lesson and verifying student understanding is critical at this point.

2.8.5. Evaluation

Although the fifth phase is devoted to evaluation, a skillful teacher evaluates throughout the 5E model, continually checking to see if students need more time or instruction to learn the key points in a lesson. Ways to do this include informal questioning, teacher checkpoints, and class discussions. Each lesson also includes a formal evaluation, such as a written quiz or poster session. These formal evaluations take place at the end of the lesson.

In summary the 5E learning cycle lesson plan would be to:

1) garner students' interest in the topic of the day;

2) discover what they already think they know;

3) present more accurate information grounded in research;

4) allow students to apply their new knowledge, and

5) evaluate/assess the results.

The results of numerous studies have revealed the effectiveness of the learning cycle on the educational results like achievement, scientific attitudes and thinking skills at all levels, which are fundamental objectives of the scientific education, and appeared in the general outlines of science curriculums in Jordan (The Ministry of Education, Jordan, 2006)

According to Qarareh (2012), the learning cycle strategy makes great strides in the educational field as an effective teaching strategy due to its harmony with the nature of science and that the subject is a scientific knowledge and research and thinking method, and also because its attaches great importance to the learner. Adams, Bevevino, & Dengel (1999) have explored the 5E instructional model approach in their study. It was found that the 5E instructional model encouraged students to develop their own frames of thought.

Cavallo (2003) in a study examined students' interpretations of chemical reactions using open-ended questions during the learning cycle, with a study sample of (60) students of the ninth primary grade, the results revealed an improvement in students understanding when implementing the learning cycle as compared to the students who studied using the traditional method.

In a study, Kevin (2003) investigated the effect of the constructivist learning cycle on students' achievement in studying the law of mechanics. The study sample consisted of two groups: (1) an experimental group studied using the learning cycle, and (2) a control group studied using the traditional method. The results of the study showed a higher achievement of the experimental group.

Researchers in science education have established that students' alternative conceptions in science are very tenacious and that traditional instruction is not very effective in promoting conceptual understanding (Wandersee et al. 1994; Driver et al. 1985).

Lindgren and Bleicher's (2005) findings were applied on 40 teachers of the primary stages and showed that implementing learning cycle had greatly improved on teachers' understanding and increased students' comprehension of the scientific concepts.

The 5E model is a model that promises to promote student understanding of science. This is manifest by several recent studies in science education that have used constructivist 5E Model in varying contexts using a variety of science topics (Aydede et al. 2010; Bryce and Macmillan, 2005; Hardy, Joen, Moller, & Stern, 2006; Tural, Akdeniz, & Alev, 2010). For example, in their study of an eighth-grade genetics class, Balci, Cakiroglu, and Tekkaya, Çapa, & Yılmaz, (2006) made a comparison of the effectiveness of the 5E Learning Cycle with the effectiveness of expository instruction. According to their conclusions, the activities for students in the 5E Learning Cycle helped them to activate their prior knowledge and to overcome their struggles with their misconceptions.

In addition to the knowledge gains, these students had the opportunity of interacting that helped the students further extend the conceptual understanding. Thus a few misconceptions that they held are corrected.

All the above studies reveal that the 5E model is successful in facilitating conceptual understanding. Hynd, McWhorter, Phares, & Suttles (1994) Posner, Strike, Hewson & Gertzog, (1982) tend to agree that conceptual change models concentrate on Piaget's ideas and principles of constructivist learning theory.

Four conditions need to be present in order for students to undergo a conceptual change (Mestre, 1994). These are:

1. Student dissatisfaction with an existing conception. (If an explanation makes sense to the student and is unchallenged, there is no motivation to change it.)

2. Students must have some minimal understanding of the concept or they will not appreciate its meaning.

3. Students must view the new concept as plausible or they will not give it serious consideration.

4. Students must see the new concept as useful for interpreting or predicting phenomena.

2.9 Concept of Diffusion and Osmosis

According to Odom and Barrow (1993), diffusion and osmosis are seminal concepts, because they are related to many aspects of living organisms, and serve as key concepts to understanding of important life processes that students frequently encounter in their daily life. Thus, these concepts need to be learned and taught well.

The concepts of transport across cell membrane, i.e., diffusion, osmosis and active transport are very important for biology students for sound understanding of the functioning of the cell. Diffusion is the primary method of short distance transport in cells and cellular systems. Osmosis is used to explain water uptake by plants, turgor pressure in plants, water balance in aquatic creatures and transport in living organisms (Odom, 1995). Unfortunately students find these topics very difficult to understand (Friedler, Amir, & Tamir, 1987).

Students may connect diffusion and osmosis in nature and other daily life process around them. The concept of diffusion can be easily understood in terms of how the substance transitions and gas exchange occurs in body cells. This is because diffusion is one of the short distance transport methods in cells and cellular systems (Odom & Barrow, 1993).

Sanger and Sanger (2001) conclude in their study that students are unfamiliar with particulate drawings, they may misinterpret these drawings. Most of the concepts in diffusion and osmosis are closely related to concepts present both in chemistry and in physics, such as solutions, particulate nature of matter, and permeability. Consequently understanding of these concepts requires the understanding and application of knowledge in physics and chemistry as well as biology. Johnstone & Mahmoud (1980) have observed that osmosis is regarded by teachers and students as being among the most difficult biological concepts to understand.

2.10 Misconceptions

The concepts of diffusion and osmosis are critical for understanding life processes. They are introduced in many biology courses (e.g. general biology, cell biology, physiology, ecology). They are also closely related to concepts in physics and chemistry, such as permeability, solutions, and the particulate nature of matter (Friedler et al., 1987). Several science education researchers have reported student misconceptions associated with these topics (Marek, 1986; Zuckerman, 1994; Odom & Barrow, 1995). One reason why students may have difficulty with the concepts of diffusion, osmosis and active transport is that these concepts require students to visualize and think about chemical processes at the molecular level (Johnstone & Mahmoud, 1980; Friedler et al., 1987; Westbrook & Marek, (1991).

Odom and Barrow (1995) believe that students have difficulties with the concepts of diffusion and osmosis because: (1) formal reasoning skills are required to understand these two processes, (2) making sense of these constructs subsumes understanding of other technical concepts, e.g. solution, solute, solvent, semi-permeability, molecular movement, net movement and direction of movement, and (3) there is often confusion between the vernacular and scientific usages of terms, e.g. pressure, concentration and quantity.

Diffusion and osmosis concepts are typically abstract, because they are the movements of biological materials. Hence, most students hold some mistakes or misconceptions about the concepts in their mind (Tekkaya et al., 2000). Odom and Kelly (2001) state that it is important that the concepts are to be fully understood by students because they often come across them in their daily life. Students who fully understand the concept of diffusion and osmosis can make constructive comments about their own metabolism and the scientific events in nature they come across.

Calik and Urey (2008) are of the view that despite the fact that student's pre-existing idea is very crucial for further learning, an unstructured (or structured inaccurately) idea may generate an obstacle to achieve conceptual learning. Such incorrect views are generally named misconceptions, different from those accepted by scientific community. The misconceptions held by students are also pieces of intellectual thought in case of concepts.

The challenges science teachers face in lesson delivery remains: *Why is it so difficult to successfully teach for students to understand the concepts of osmosis and diffusion?* This may be partly due to the fact that these processes result from the constant, random motion of invisible particles, and a significant number of students struggle to comprehend such abstract ideas. While students understood that there is a random component to biological processes (e.g., diffusion), students were unable to link this randomness to emergent systematic behaviors (e.g., net movement of particles through a membrane) (Garvin-Doxas & Klymkowsky, 2008).

Why misconceptions arise can be explained by several factors such as student's insufficient prior knowledge, his/her bias, his/her deficiency of motivation, teacher's insufficient content knowledge, paying more attention to details instead of concepts, textbooks including misconceptions, using daily life language instead of scientific one and cultural factors, meaning that some concepts may lead to different meanings in various cultures (Harrison., 1998; Lubben, Netshisuaulu, & Campell, 1999).

Artun and Costu, B (2011) in a study concluded that primary student-teachers held some misconceptions about various aspects of the diffusion and osmosis. The main reason why they held this misconception as supported by Westbrook and Marek (1991) is that primary student-teachers have little abstract thinking ability about the concepts.

2.11 Attitude of students towards learning science

Attitude is an important concept in social judgments and behaviors and thus, is one of the most important concepts in decision making (Venkatesh & Morris, 2003). Thus altitude gives an indication of how to handle situations.

There is no consensus among researchers on the meaning of attitude. Different researchers define attitude differently. Indeed, many researchers interchangeably use the words attitude and interest. Gardner (1975) defined attitude as "a learned predisposition to evaluate in certain ways objects, people, actions, situations or propositions involved in learning science". Salta and Tzougraki (2004), also defined attitude as "the tendency to think, feel or act positively or negatively towards objects in our environment". According to Yara (2009), attitude towards science means interest or feeling towards studying science. It is the students‟ tendency to liking or disliking science.

Many factors could contribute to student's attitude towards studying integrated science. According to Hendrickson (1997) attitudes are the best predictor for estimation of students' success. Furthermore, Halladyna and Shanghnessy (1982) have found a number of factors related to students' attitude to science. Such factors include teaching methods, teacher's attitude, influence of parents, gender, age, cognitive styles of pupils, career interest, societal view of science and scientists, social implications of science and achievement.

Attitudes are acquired through learning and can be changed through persuasion using a variety of techniques. Attitudes, once established, help to shape the experiences the individual has with object, subject or person. Although attitude changes gradually, people constantly form new attitudes and modify old ones when they are exposed to new information and new experiences (Adesina & Akinbobola, 2005).

One of the factors that could influence the student's attitude is the method of instruction. Aiyelaagbe (1998) reports of a more positive attitude of students after exposing them to self-learning strategy.

In conclusion, this chapter reviewed literature by experts in different spheres of study relevant to the subject under study as well as the researchers' view on the topic. The discussion was focused on the concept of understanding models, constructivist theory, 5E learning cycle as well as the concept of diffusion and osmosis and students' misconception on diffusion and osmosis and the attitude of students towards science. Numerous studies conducted using the 5E instructional model, evidence repeatedly reveals that the model increases the success of students, elevates their conceptual understandings and positively changes their attitudes (Baker & Piburn, 1997; Tandel, and Pinalben , 2006). Researchers report that generally students have many inaccurate conceptions and misconceptions about diffusion and osmosis, and that they find these two concepts difficult to differentiate (Friedler et al., 1987; Friedrichsen & Pallant, 2007).

CHAPTER THREE

METHODOLOGY

3.1 Overview

This chapter describes the research design employed in this research, the study area for the research, the research population, sampling procedure, research instruments and intervention strategy, method used to collect data and analysis of data to examine the effects of the 5E model on students conceptual understanding St. Fidelis Senior High School.

3.2 Research Design

Mixed quantitative and qualitative research was selected for the research design. Creswell (2003), recognizing that all methods such as observations and interviews (qualitative data) combined with traditional surveys (quantitative data) have limitations, notes that researchers feel that biases inherent in any single method can neutralize or cancel the biases of other methods.

A pre-test and post-test with control and experimental groups were carried out for the study. The second year class of St. Fidelis Senior High School is organized into two classes for the core subjects A (Arts1 and Arts2) and B (Agric, Business and Home Economics). These two classes were randomly assigned as control and experimental groups. The experimental design pattern is shown in Table 1. In the pattern, B was experiment group while A was the control group. First measurement done by performing a pre-test and second measurement is done after intervention by performing a post-test.

Table 1: The Experiment Design Pattern

Groups	Pre-test	Experiment treatment	Post-test
Experimental group	B	X	B
Control group	A	-	A

After instruction, based upon the 5E Instructional Model, students completed the 5E Inquiry Based Instruction Questionnaire and assessed their comfort in learning from constructivist-based instruction. Student comments provided further understanding into their selections.

This study examined whether or not activities prepared according to the 5E instructional model had an impact on student achievement. Experimental and control groups were composed of total 64 students studying at St. Fidelis Senior High School. There were 32 students in each of experimental and control groups. Lessons were given in both groups with two different methods for two weeks. Both the control group and the experimental group from second year class were taught by the same person.

3.3 Study area

The study was conducted at a co-educational Senior High School, St. Fidelis Senior High School. The school was established in 1991. Currently, there are about 350 students and 26 teachers. Most students in the school come from lower middle-class and poor families in the rural areas of Ghana. The school was chosen, because it could provide the researcher with sufficient resources and adequate facilities to conduct and complete the study. Moreover, the school Acting Headmaster then and current substantive Headmaster of the school showed a strong support and encouraged teachers in the school to learn new things from the study to improve their teaching and students' learning.

3.4 Research Population

The population of the survey was constituted by second year students of St. Fidelis Senior High School in the Kwahu Afram Plains South District in the Eastern Region of Ghana. However, the second year students of St. Fidelis Senior High School numbering about 121 were purposively chosen for the research because they were not under pressure to write any external examination neither were they new to concepts in integrated science.

3.5 Sample and sampling procedure

Classes were randomly assigned as the "control" (traditional method of instruction) and "experimental" (5E Model method of instruction) groups. The total sample size was 64 made up of 32 experimental (B class) and 32 (A class) control group of both male and female students. Simple random sampling was used to select the size of 64 students from the 121 students. In order to ensure the equivalence at experimental and control groups, students' previous year exam scores were examined and pre-test was conducted to verify the comparability of knowledge of diffusion and osmosis of the two groups. Three (3) science teachers and one (1) administrator were included to ensure the effectiveness of the study.

The single pre-test and post-tests were preferred to establish baseline data through administering one single pre-test to establish confidence in the effectiveness of the methods considered and their treatment procedures. This reason agrees with Wiseman's

(1999) stand that if a group scores approximately the same on each of the pre-test and then, after the treatment, improves significantly on the post-tests, the researcher has grounds for more confidence in the effectiveness of that treatment. The pre-test was administered once, and the contents of the post-test were copied from the instrument used for pre-test and the items were restricted to the contents covered in period of instruction.

3.6 Research Instrument /Tools

Three main assessment instruments, that is subject matter pre-test and post-test (Diffusion and Osmosis Diagnostic Test (DODT), the Inquiry-Based Instruction Questionnaire and observation were employed to answer the research questions in the study. They are explained further into more detail in the sub-sections that follow.

3.6.1 The Diffusion and Osmosis Diagnostic Test (DODT)

To ascertain students' understanding and misconceptions about diffusion and osmosis, Diffusion and Osmosis Diagnostic Test (DODT) adopted from Odom and Barrow (1995) was used in the pre-test and post-test. This test has been proven to be an effective instrument in assessing students' understanding of the concepts of diffusion and osmosis (Odom & Kelly, 2001).

The DODT is a validated two-tier diagnostic test designed to assess understanding of diffusion and osmosis concepts. The DODT comprised of a 12 two-tier multiple choice format. Items for the diagnostic instrument were based on the two-tier multiple-choice format by Odom and Barrow (1995). The first tier consisted of a content question with two, three or four choices. The second tier consisted of four possible reasons for the first part: three alternative reasons and one scientifically accepted reason. The conceptual areas covered by the test were particulate and random nature of matter, concentration and tonicity, the influence of life forces on diffusion and osmosis, the process of diffusion and the process of osmosis.

Prepositional knowledge statements are used to define content boundaries of diffusion and osmosis concepts. A list of 22 prepositional knowledge statements required for understanding diffusion and osmosis at a level of sophistication appropriate for senior high school students were identified (appendix D). All 22 propositional knowledge statements were matched to the items on the Diffusion and Osmosis Diagnostic Test. All of the questions, except one, incorporated more than one of the propositional knowledge statements. Item 4 matched only propositional knowledge statement 5, which is concerned with concentration as measured by the number of particles per unit volume (appendix E).

3.6.1.1 Scoring the items

An item was scored correct on the Diffusion and Osmosis Diagnostic Test if both the desired content and reason answer were selected. Items were evaluated for both correct and incorrect response combinations selected as indicated in Table 2.

Table 2: Criteria for Analyzing the Two-Tier Test Items

Categories Marks			Marks
First tier	**Second tier**		
True response	True reason	(T – T)	3
False response	True reason	(F – T)	2
True response	No reason	(T – N)	2
True response	False reason	(T – F)	1
False response	No reason	(F – N)	0
False response	False reason	(F – F)	0
No response	No reason	(N – N)	0

(Adopted from Odom and Barrow, 1995)

3.5.1.2 Validity of DODT

The content validity of DODT was established by submitting the test (appendix A) as well as appendix C and D to three qualified science teachers at the senior high school level. They established whether the test items and the concepts tested were within the content of diffusion and osmosis as specified in the syllabus. They also ascertained whether the level of difficulty in the items selected in the DODT were appropriate to the form two senior high school students. These items were designed to measure students' understanding of diffusion and osmosis and were used to compare subject-matter knowledge of students in the control group and experimental group.

3.6.2 5E Based Instruction Questionnaire

A questionnaire designed to determine students' attitudes toward 5E instructional model in the science classroom was applied in the study. Students completed the 5E inquiry based instruction questionnaire (adapted from Neo & Neo, 2009) to assess their comfort in learning from the constructivist-based instruction, hence attitude. Students responded to a series of statements by either selecting *Agree* or *Disagree* and then elaborates further by providing comments (Appendix C).

The two point scale was adopted because it makes relative comparisons meaningful and makes it easier for the students per their level comprehension. Also *Neutral* points attracts respondents, who actually slightly lean toward a favorable or unfavorable response (Sauro, 2011). The basic assumption behind attitude scale is that it is possible to uncover a person's internal state of beliefs, motivation, or perceptions by asking them to respond to a series of statements (Fraenkel & Wallen, 1996). The mean percentage of students who selected *Agree* on the questions pertaining to learning style was compared to those who selected *Disagree* to determine the impact of the treatment on student comfort. Student comments provided insight into their selections.

3.7 Pilot Study of Instruments

The DODT was tested with a sample of 20 SHS 3 students from the same secondary school as the students who participated in the study. These students did not participate in the actual study. The DODT was pilot-tested to:

1. improve the validity and reliability of instrument. Items that were too difficult could be rephrased, while the terms or wording could be modified whenever necessary;
2. identify and clarify any unanticipated problems and difficulties which might arise during the actual study; and
3. help refine the research procedures such as test administration, scoring procedures and data analysis

3.8 Validity and reliability of the instruments

Nitko (2001) notes that validity is the soundness of the interpretations and uses of student's assessment results. It can also be defined as the appropriateness or correctness of inferences, decisions, or descriptions made about individuals, groups or institutions from test results. Golafshani (2003) validity describes whether the means of measurement are accurate and whether they are actually measuring what they are intended to measure. In order to ensure the content validity of data collected, five (5) colleague teachers, including three (3) science teachers scrutinized the DODT and Inquiry-Based Instruction Questionnaire items to offer relevant suggestions for improvement. This helped to improve the validity of the instruments.

A Test-retest was carried out using SPSS version 17 on DODT. Test-retest reliability can be defined as "a measure of the reproducibility of the scale, that is, the ability to provide consistent scores over time in a stable population" Aaronson, Alonso, Burnam, Patrick, Perrin & Stein (2002). Test-retest (Stability) reliability coefficient was found to be 0.913, indicating a high level of consistency of the instrument. This agreed with the recommendations of Wiseman (1999) that reliability has to do with accuracy and precision of a measurement procedure, a high reliability value of 0.70 or higher shows that the test is reliable (accurately) measuring the characteristic it was designed to measure.

3.9 Intervention strategy

Two treatments were used in the study:

1. Teaching using traditional method (control group); and
2. Teaching using 5E model (experimental group),

Both groups were taught by the researcher. The study was carried out in the second term of the 2013/2014 academic year. In order to check the implementation of both treatments in control and experimental groups, classroom observations were carried out. In the control group, implementation of instruction based on traditional method was used while in the experimental group implementation of instruction based on 5E learning cycle model was analyzed carefully. During the process of observation, the interaction between teacher-students and students-students; participation and contribution of students into learning environment; behaviour and attitude of students as well as the physical conditions and material availability of the classroom was observed. Before observation of the real implementation process, the researcher visited the classrooms was 2 times, sat silently at the back and observed the classroom.

The 5E instructional model activity was used in the experimental group; traditional teaching took place through the use of question and answer methods. Diffusion and Osmosis Diagnostic Test (DODT) was used as a test instrument. Both the pre-test and post-test were scored out of 36. The achievement test was given to both groups as pre-test and post-test. The implementation continued in both groups for a period of two weeks.

3.9.1 Teaching Approaches Used with the Experimental Group (5E Model Teaching Activities)

In this study, the 5Emodel based on the constructivist learning theory was used to improve assess senior high school students' conceptual understanding of diffusion and osmosis. The goal at this stage was to maximize students' active involvement in the learning process. The teaching activities related to each of the stages of the 5E model are outlined below.

3.9.1.1 Diffusion

3.9.1.1.1 Engage Stage

To engage prospective students in exposing their prior understandings of the concept of diffusion, they were asked to observe the following activity and answer related to the concept of diffusion in order to disclose pre-instructional knowledge and instill interest by students. An individual observing three beakers that demonstrated the diffusion of ink in water in progressive time period and the related question was: How does a drop of ink spread in a beaker of water? The goal at this stage was to increase students' attention, get them interested and ready to learn.

3.9.1.1.2 Explore Stage

The explore stage consists of the students answering the question that was posed to them in the ''engage stage'' by playing a game related to diffusion with their peers and individually answering the following questions: ‘‘Define diffusion’’ ‘‘What causes molecules to move around? Explain the relation between temperature and diffusion rate. How do you think ink dyes the water?’’ They also discussed and interacted with each other. Teacher only provided questions, suggested approaches, gave feedbacks, and assessed understandings.

3.9.1.1.3 Explain Stage

The researcher, who teaches science course, provided scientific explanations with appropriate examples. The teacher guided students toward coherent and consistent generalizations, helped students with distinct scientific vocabulary, and provided questions that helped students to use this vocabulary to explain the results of their explorations.

3.9.1.1.4 Elaborate Stage

Students were provided activities to enhance their understanding through two activities: (1) translation of learned concepts to their personal lives; and (2) a conceptual change text about diffusion. Subsequently, students were given an opportunity to demonstrate their new understandings by integrating the acquired knowledge through the game activity, the instruction given by the researcher, translation of concepts into their personal lives, and a conceptual change text about diffusion. A discussion of all the activities in the classroom culminated in elaborating students’ understandings of the concept of diffusion.

3.9.1.1.5 Evaluate Stage

The evaluate stage consists of assessing students' understanding of the concept of diffusion, which consisted of three new related questions. An example is as follows: ‘‘While Helena had breakfast, her mother served her a cup of tea with cubes of sugar. Helena added a cube of sugar into her cup of tea and stirred it to make it sweet. This activity demonstrates the concept of diffusion because sugar molecules are equally dispersed in the cup of tea.’’ Following this scenario was a question asking students to give examples of diffusion from real life to evaluate whether they had understood the concept of diffusion. For evaluation purpose, students were also asked the following question: Discuss what would happen if diffusion did not occur?

3.9.1.2 Osmosis

3.9.1.2.1 Engage Stage

To engage prospective students in exposing their prior understandings of the concept of osmosis, they are asked to perform the following activity and answer a related question. “Peel the yam tuber, cut it into two parts, and make a cavity with the aid of the knife into the two cut yam tubers. Pour water into the two Petri-dishes. Place each half of the yam tubers with base down into the Petri-dishes containing water. Add small quantity of sugar to yam tissue A and allow yam tissue B to serve as control experiment.” The set-up was allowed to stand for 4-6 hours. The related question was: “How does water move across the yam membrane into the sugar solution?”

3.9.1.2.2 Explore Stage

The explore stage consisted of the students answering the question that was posed to them in the ‘‘engage stage’’ by playing a game related to osmosis with their peers and individually answering the following questions: ‘‘Define osmosis’’ ‘‘what causes water molecules to move through the yam tissue with sugar solution?” Explain why water molecules did not move across the yam membrane that did not contain sugar?’ They also discussed with each other.

3.9.1.2.3 Explain Stage

The researcher, who teaches the subject integrated science, provided scientific explanations with appropriate examples and questions from the students were answered. This was to clarify doubts and define relevant terms.

3.9.1.2.4 Elaborate Stage

Students were provided activities to enhance their understanding through activities such as the teacher drawing an image on the board. Students must predict what a plant look like in a salt solution through a written statement and a drawing. They supported their statements with evidence from their previous investigation. Subsequently, students were given an opportunity to demonstrate their new understandings by integrating the acquired knowledge through the game activity, the instruction given by the teacher, translation of concepts into their personal lives, and a conceptual change text about osmosis. A discussion of all the activities in the classroom culminated in elaborating prospective teachers’ understandings of the concept of osmosis.

3.9.1.2.5 Evaluate Stage

The evaluate stage consists of assessing students' understanding of the concept of osmosis, which consisted a few related questions. An example is as follows: ‘‘Fishermen would store their fish by cleaning them, then covering them in salt. The pieces of fish eventually become hard and stiff as a board! Does osmosis help explain what happened to the fish?’’ Subsequent to this scenario was a question asking students to give examples of osmosis from real life to evaluate whether they had understood the concept of osmosis. They were also asked to discuss the relevance of osmosis in real life situations.

3.9.2 Approach with the Control Group

A traditional instruction method was used with the control group. The researcher used direct teaching and question and answer methods to teach related topics and basic concepts. Basic explanations and question and answer methods suited the traditional teaching approach where students are completely passive, were used in teaching the diffusion and osmosis. Teaching strategies embodied the use of the researcher's explanations and textbooks.

Instruction was provided by researcher through lecture and discussion methods to teach the concepts. The entire class was structured as a unit, notes were written on the chalkboard about the definition of concepts. The fundamental principle is that there is transfer of knowledge from the teacher to the students. The teacher explained the concepts of diffusion and osmosis and directed questions that prompted discussions. Worksheets were developed specifically for each lesson.

Written responses were required from the students which were collected and corrected. Each lesson, in general, consisted of presenting the correct way to work out problems. Much of the instructional time was devoted to instruction and engaging in discussion that arised from the researcher's explanation and questions. The idea is that there is a fixed body of knowledge that the student must come to know. Students are expected to blindly accept the information they are given without questioning the instructor (Stofflett, 1998), under the traditional method of teaching.

3.10 Data collection procedure

The data were collected by the researcher himself. For the data collection prior permission was sought from the Headmaster of St. Fidelis Senior High School. According to time schedule, two weeks was given to the experimental group and control group. The experimental group was taught through the 5E model and the control group was taught through traditional lecture method. Both groups were taught after the pre-test. At the end of the teaching period, the post-test was given to students and the data collected were used to test the hypotheses.

At the end of the study, a questionnaire survey was introduced to students in the experimental group to gather information regarding their attitudes toward using the 5E instructional model in the science classroom.

3.11 Data Analysis

The data on test scores as well as data on questionnaires were put forward according to the responses of students. The data analysis was carried out using SPSS version 17.0 for Windows and Microsoft Excel 2010. In order to analyse the instructors' implementation of the 5E learning model according to the student views and the relationship; mean, standard deviation, frequency and percentage calculations were used. One-way Analysis of Variance (one-way ANOVA) is a technique used to compare means of two or more samples using the F distribution (Howell, 2002). Although typically it is used to compare means of three or more samples, it can be used for comparison of two sample means in this research.

3.12 Summary

This chapter looked at the methodology that was used by the researcher for the study. This includes research design, population for the study, sample and sampling techniques used, research instrument, research intervention, data collection procedure and method of data analysis.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Overview

In this chapter, the results of the research work are presented. They are presented in the order of the statement of the research questions. The sub-sections also include: analysis of achievement gains of students. Again, some results of students' misconceptions were identified. Finally, results of questionnaire on the attitude of students towards toward science are presented.

4.2 Analysis of Findings Related to Research Questions

4.2.1 Research Question 1: What is the effect of the 5E model on second year students of St. Fidelis Senior High School of understanding the concept of diffusion and osmosis?

Statistical tools were used for the analysis of the collected data. One-way Analysis of Variance (ANOVA) was used to compare the treatment groups on achievement and to test for significant difference between students' pre-instructional and post-instructional test scores. A sample of pre-test and post-test of two students, one in the control group and the other in the experimental group is presented in Appendix B.

With respect to the pre-test scores, all the participants in the two groups were equivalent regarding the knowledge of the concepts before the treatment as shown in Table 3. This was demonstrated by comparison of their mean scores and confirmed with the one-way ANOVA test at $p = 0.05$. Table 3 shows that students taught with the 5E learning cycle scored hight marks than those taught by the traditional method. On the comparison of the pre-test and post-test means, the data indicated an improvement of 7.78 from 10.56 to 18.34 out of a total of 36 marks for the traditional method and improvement of 11.21 from 11.22 to 22.59 out of 36 marks for 5E model on achievement. However, comparison of post-test mean scores indicated a relatively higher mean for 5E model (22.59) than the traditional method (18.34) a difference of 4.25 marks.

Table 3: Comparison of Pre-Test and Post-Test Achievement Means of the 5E Learning Model and Traditional Method Groups

Test type/instructional method	N	Mean	SD
(a) Pre-test			
5E model	32	11.21	3.61
Traditional	32	10.56	3.57
(b) Post-test			
5E Model	32	22.59	4.81
Traditional	32	18.34	5.47

The concepts of transport across cell membrane i.e. diffusion, osmosis and active transport are very important for biology students for sound understanding of the functioning of the cell (Odom & Barrow, 1993). The pre-test results of the present study clearly showed poor understanding of the processes of diffusion and osmosis for the control and experimental groups (Table 3).

Some biology concepts are very difficult for teachers to teach as well as for students to learn due to the abstract nature of the concepts and the processes involved that are not physically observable. Hence, for better understanding of the concepts of membrane transport, visualization of chemical processes at molecular level is required (Johnstone & Mahmoud, 1980; Friedler et al., 1987; Westerbrook & Marek, 1991).

The one-way ANOVA comparison of groups shown in Table 4 revealed that there was no significant difference ($p > 0.05$) at the beginning between the means of pre-test scores of the 5E model and traditional method groups in terms of students' achievement of Diffusion and Osmosis Diagnostic Test (DODT) ($p > 0.05$) before treatment. The calculated F value was less than the critical F value (Table 4). With this result, **Ho:1** was retained because there is really no significant difference in pre-test scores between students taught with 5E model and traditional method. Therefore, the two groups could be treated as comparable groups.

Table 4: ANOVA of Pre – Test Scores of 5E Model and Traditional Method Groups

Source of variation	SS	df	MS	F	P – value	F crit
Between groups	6.890625	1	6.890625	0.533128	0.468045	3.995887
Within groups	801.3438	62	12.9249			
Total	808.2344	63				

The results from the one-way ANOVA suggested that there was a significant difference ($p > 0.05$) between the mean of pre-test scores and the mean of post-test scores of traditional method (Table 5). With this result, **Ho:2** was rejected because there was significant difference in pre-test and post-test scores of students taught with the traditional method.

Table 5: ANOVA of Pre and Post – Test Scores of Traditional Method Group

Source of variation	SS	df	MS	F	P – value	F crit
Between groups	968.7656	1	968.7656	53.96084	0.00000	3.995887
Within groups	1113.094	62	17.95313			
Total	2081.859	63				

The results from the one-way ANOVA suggested that there is a significant difference ($p < 0.05$) between the mean of pre-test scores and the mean of post-test scores 5E model method (Table 6). With this result, **Ho:3** was rejected since means of the pre-test scores was significantly ($p < 0.05$) lower than that for the post test scores of the 5E method.

Table 6: ANOVA of Pre and Post – Test Scores of 5E Model

Source of variation	SS	df	MS	F	P – value	F crit
Between groups	2070.25	1	2070.25	96.1329	0.00000	3.9958
Within groups	1335.19	62	21.5353			
Total	3405.44	63				

The results from the one-way ANOVA showed that there is significant difference ($p < 0.05$) between the mean of post-test scores of the 5E model of instruction and traditional method. With this result, **Ho:4** was rejected since mean of post-test scores of the 5E model is significantly ($p < 0.05$) higher than the post-test scores of the traditional method of instruction. This indicates that the students instructed by 5E model of instruction gained more achievement than the students instructed by traditional method.

Table 7: ANOVA of Post – Test Scores of 5E Learning Model and Traditional Method Groups

Source of variation	SS	df	MS	F	P – value	F crit
Between groups	289	1	289	10.8796	0.00161	3.99589
Within groups	1646.94	62	26.5635			
Total	1935.94	63				

Figure 1 shows the percentage distribution of control and experimental group scores in the Post-test. It is evident from the graph that the students in the experimental group (5E Model group) achieved relatively higher marks than their counterparts in the control group (traditional method).

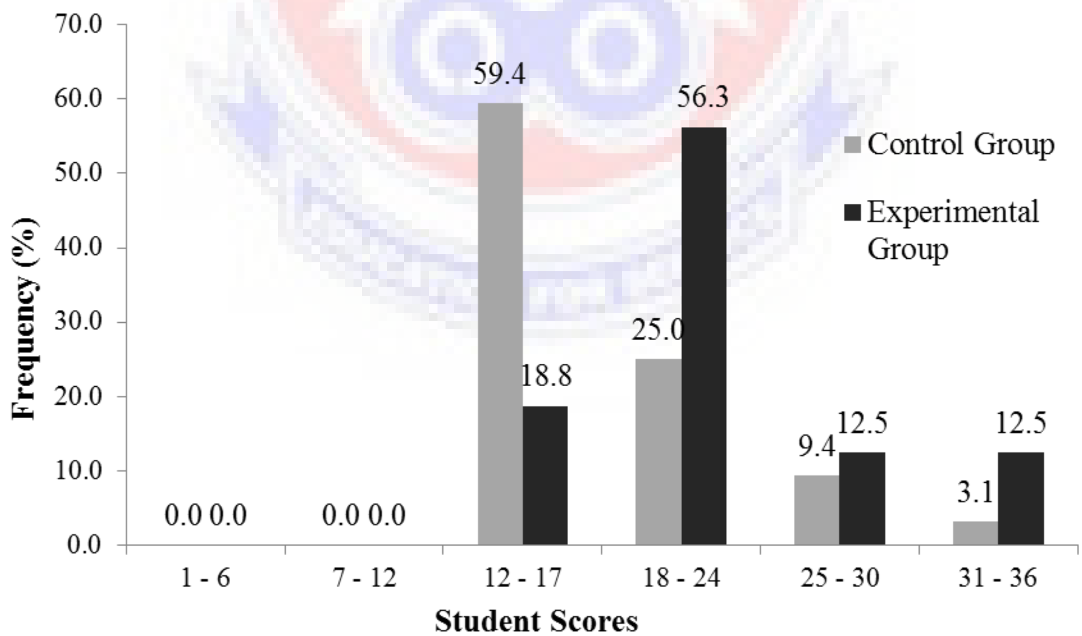

Figure 1. Percentage Distribution of Control and Experimental Group Scores in the Post-Test.

The higher achievement of students in the 5E model group as compared to the lower achievement of students in the traditional group is noteworthy. The ANOVA analysis showed that the method of teaching does predict students' achievement in groups with varying instructional methods. However, while the unique and significant effect of 5E model on students' achievement over and above lecture method is applauded, there were several specific observations that were made about the findings in relation to the two instructional methods. First, the analysis indicated that the two methods had significant effects on students' achievement in science. Since the post-test scores of all the students in the two groups were significantly greater than their pre-test scores, it therefore follows that the post-test achievement scores was earned not by chance but as a result of treatment with the prescribed instructional methods. This implies that both methods compared have the potential to cause learning to take place but at varying degrees which was the basis for this study. The ability of this study to establish a cause and effect relationship as found, agrees with the principle of experimental research as recommended by Wiseman (1999). It has been agreed that in experimental research, a treatment must be confirmed to be responsible for any difference noticed.

Secondly, the analysis showed a significant difference in achievement scores between the 5E model and traditional instructional groups. The data analysis of the present study showed that the mean score (22.59) of the 5E model group was significantly higher ($p < 0.05$) than the mean score (18.34) of the traditional method group in the Diffusion and Osmosis Diagnostic Test (DODT). The variations in achievement scores between the two groups may be due to the variation in the teaching strategies adopted in each of the groups and their comprehension of the methods of instruction. Students taught with 5E model strategies outscored those taught with traditional method suggests that the students in the 5E model group may have been more active in the learning process than those in the lecture group and thus contributing to their higher achievement scores. This is hinged on the assertion that students learn better by doing (Gordon, 2009). The low achievement scores as found among the students taught with traditional method may not be unrelated with the transmission approach involved, where the teachers pass over their knowledge to their pupils.

The significantly higher achievement of students taught with 5E model over those taught with lecture method as found in this study is consistent with the findings of earlier researchers on this same subject matter (Adams et al., 1999, Cavallo, 2003; Kevin, 2003)

Diffusion and osmosis as a topic includes abstract and theoretical concepts (Johnstone & Mahmoud, 1980; Friedler et al., 1987; Westbrook & Marek, 1991). For this reason students have difficulty in understanding the diffusion and osmosis concepts. So, it can be concluded that, while teaching diffusion and osmosis concepts, the teachers should make the scientific concepts as concrete as possible. Children's prior knowledge of phenomena is an important part of how they come to understand school science. Therefore, teachers also should be more sensitive to student's prior knowledge.

Through the instruction designed according to 5E model, the teacher was aware of students prior knowledge. Since learning is a social process, students worked in groups with their friends. So interaction is maximized through this way. In the learning process as rightly put by Bybee (2002), students also made hands-on and minds- on activities. They participated actively in instruction. In this strategy, in the first phase of cycle called "engagement", students were asked several questions. Here the purpose of teacher was to activate students' prior knowledge. In the exploration phase, the teacher asked a question for students to explore the phenomena by themselves. In two phases, teacher let the students to discuss with their friends. In this learning environment, students made connections between the new concepts and the existing ones.

4.2.2 Research Question 2: What are some of the misconceptions held by second year students of St. Fidelis Senior High School about diffusion and osmosis?

Students misconceptions were identified based on the students responses to the pre-test and post-test which are presented in Table 8. As seen from Table 8, students' misconceptions changed (pre-test and post-test). It shows a decrease in terms of the number of students who had misconceptions prior to the implementation of the 5E instructional method. A total of 16 misconceptions were identified with the pre-test as seen in Table 8, however after the intervention, SM#1 SM#10 and SM#16 were seen to have been corrected after the post-test.

Diffusion is a concept that students in high school biology should understand. Yet there is much evidence that points otherwise. Westbrook and Marek (1991) demonstrated that despite instruction, misconceptions about diffusion persisted. They found that college freshmen in zoology expressed as many misconceptions about diffusion as seventh-grade life science students (37% and 38%, respectively). The results of the Diffusion and Osmosis Diagnostic Test suggest that the students of St. Fidelis Senior High School did not acquire a satisfactory understanding of diffusion and osmosis concepts.

Table 8: Students' Misconceptions (SM) and Difficulties Elicited by Analysing each Test Item

Item	Misconceptions	Pre-test (students)	Post-test (students)
When a drop of blue dye is added to the beaker of water, after several hours the water will turn a light blue colour. This process is;	1. Osmosis	6	0
	2. A reaction between water and dye	9	3
	3. The lack of a membrane means that osmosis and diffusion cannot occur	2	1
	4. The blue dye separates into small particle and mixes with water	11	1
During the process of diffusion, particles will generally move from	5. low to high concentration	15	4
	6. There are too many particles crowded into one area, so they move to an area with little room	7	4
	7. The particles tend to move until the two areas are isotonic, and then the particles stop moving	6	2

Table 8: Students' Misconceptions (SM) and Difficulties Elicited by Analysing each Test (Continued.)

Item	Misconceptions	Pre-test (students)	Post-test (students)
If a small amount of sugar is added to a container of water and allowed to set for a very long period time without stirring, the sugar molecules will	8. be more concentrated on the bottom of the container	20	9
	9. The sugar is heavier than water and will sink	12	7
	10. There will be more time for settling	2	0
When a drop of blue dye to a container of clear water and after several hours the entire container turns light blue. At this time, molecules of dye;	11. have stopped moving	20	6
	12. If they were still moving, the container would be different shades of blue	6	2
	13. If the dye molecules stopped, they would settle to the bottom of container	10	6
	14. Molecules are liquid, if it were solid the molecules would stop moving	9	1

Table 8: Students' Misconceptions (SM) and Difficulties Elicited by Analysing each Test (Continued.)

Item	Misconceptions	Pre-test (students)	Post-test (students)
Suppose there are two large beakers with equal amounts of clear water at two different temperatures. Next, a drop of green dye is added to each beaker of water. Eventually the water turns light green. Which beaker became light green first?	15. Diffusion moves faster at low temperatures	17	6
	16. It helps the molecules to expands	4	0

Based on the information presented in Table 8, a matrix of possible types of changes was constructed (see Table 9). As seen from Table 9, four different types of possible changes were observed in the students' misconceptions. Although all possibilities were observed, their frequency varied considerably, and these data are presented in Table 10. For instance the first possibility indicates the persistence of the misconception even after the intervention, whilst the second possibility indicates that after the intervention the misconception was non-existent.

Table 9: Possible Types of Changes in Students' Misconceptions and Difficulties Based on Table 8

Possibility of changes	Pre-test	Post-test	Sample changes in Table 8
1	√	√	B2 (the 1st SM)
2	√	×	B4 (the 2nd SM)
3	×	×	B6 (the 4th SM)
4	×	√	B26 (the 2nd SM)

√ Persistence of misconceptions
× The non-existence of misconceptions

Table 10 reveals positive conceptual changes. It indicates the percentage of students who still held the various misconceptions. This seems to show that student' misconceptions had decreased after the 5E model intervention. For example, percentage of the SM#1 decreased from 19 to 0% for pre- and post-tests (+19 conceptual changes occurred) and percentage of the SM#5 decreased from 75% to 13% for pre- and post-tests (+62 conceptual changes occurred).

A great difference in the performance between the pre-test and post-test after treatment was observed in some of the items. For example, in one item related to the process of diffusion, students were asked about the nature of movement of particles during the process of diffusion. Before the treatment, 75% of the students in the experimental group selected the wrong combination, which was ‘during the process of diffusion, particles will generally move from low to high concentration’. After the treatment, approximately 13% of the students in the experimental group selected that same wrong combination.

Data presented in Table 4 clearly show that after the intervention students improved in their understanding. Furthermore, students’ misconceptions reduced from the pre-test to the post-test (see Table 8 and 10). This positive conceptual change was found to be statistically significant (see Table 6). Interestingly, of the possible types of changes (see Table 9), the one most frequently observed was type 2, that is misconception in the pre-test and conceptual understanding in the post-test. These findings are consistent with the 5E model studies on various topics (Diakidoy & Kendeou 2001; Pinarbasi, Canpolat, Bayrakc, & Geban, 2006; Costu, Ayas, & Niaz, 2010).

The students had the chance to elicit their prior conceptions as well as adapt and explain their conceptions through the activities of the 5E model. As the students took part in the 5E model activities, they became dissatisfied with their prior conceptions, and thus conceptually struggled to make changes based on the 5E activities, and reinforced their understandings with scientific ideas and explanations provided by the teacher. Results showed that while some students retained their own conceptions even after the lessons, most of their conceptions reflected conceptual change. In SM#5, students' conceptions ''During the process of diffusion, particles will generally move from low to high'' decreased from pre-test (75%) to post-test (13%), a positive conceptual change (+62). SM #6 ''there are too many particles crowded into one area, so they move to an area with little room'' decreased from pre-test (22%) to post-test (13%), a positive conceptual change (+9). The reason why a few students maintained their conceptions could be because of their lack of abstract thinking (Westbrook and Marek, 1991; Odom, 1995).

SM#13 ''If the dye molecules stopped, they would settle to the bottom of container'' decreased from pre-test (31%) to post-test (19%), a positive conceptual change (+12). SM#14 ''molecules are liquid, if it were solid the molecules would stop moving'' decreased from pre-test (28%) to post-test (3%), a positive conceptual change (+25). This agrees with the assertion that students may have difficulty with the concepts of diffusion, osmosis and active transport due to their inability to visualize and think about chemical processes at the molecular level (Johnstone & Mahmoud, 1980; Friedler et al., 1987; Westbrook & Marek, 1991).

Table 10: Conceptual Changes about Students' Misconceptions (SM) and Difficulties through each Test

Item	Misconceptions	Pre-test (%)	Post-test(%)	Percentage change
When a drop of blue dye is added to the beaker of water, after several hours the water will turn a light blue colour. This process is;	1. Osmosis	19	0	19
	2. A reaction between water and dye	28	9	9
	3. The lack of a membrane means that osmosis and diffusion cannot occur	9	3	6
	4. The blue dye separates into small particles and mixes with water	34	3	31
During the process of diffusion, particles will generally move from	5. low to high concentration	75	13	62
	6. There are too many particles crowded into one area, so they move to an area with little room	22	13	9
	7. The particles tend to move until the two areas are isotonic, and then the particles stop moving	19	6	13

Table 10: Conceptual Changes about Students' Misconceptions (SM) and Difficulties through each Test (Continued.)

Item	Misconceptions	Pre-test (%)	Post-test (%)	Percentage change
If a small amount of sugar is added to a container of water and allowed to set for a very long period time without stirring, the sugar molecules will	8. be more concentrated on the bottom of the container	63	28	35
	9. The sugar is heavier than water and will sink	38	22	16
	10. There will be more time for settling	6	0	6
When a drop of blue dye to a container of clear water and after several hours the entire container turns light blue. At this time, molecules of dye;	11. have stopped moving	63	19	44
	12. If they were still moving, the container would be different shades of blue	19	6	13
	13. If the dye molecules stopped, they would settle to the bottom of container	31	19	12
	14. Molecules are liquid, if it were solid the molecules would stop moving	28	3	25

Table 10: Conceptual Changes about Students' Misconceptions (SM) and Difficulties through each Test (Continued.)

Item	Misconceptions	Pre-test (%)	Post-test (%)	Percentage change
Suppose there are two large beakers with equal amounts of clear water at two different temperatures. Next, a drop of green dye is added to each beaker of water. Eventually the water turns light green. Which beaker became light green first?	15. Diffusion move faster at low temperatures	53	19	4
	16. It helps the molecules to expand	13	0	13

4.2.3 Research Question 3: Will the use of the 5E instructional model bring any change in the attitude of second year students in St. Fidelis Senior School toward science?

Students responded to a series of statements about inquiry-based projects by either selecting *Agree* or *Disagree* and then elaborated further by providing comments (Appendix B). The percentage of students who selected *Agree* was compared to the percentage of students who selected *Disagree.* The findings from the survey are exhibited in Table 11.

Furthermore, the mean percentage of students who selected *Agree* on the questions relating to learning style was compared to the mean percentage of students who selected *Disagree* (Figure 2) to determine the impact of the treatment on student comfort. Student comments provided insight into their selections. Overwhelmingly about 94% had a relatively positive attitude towards the new approach as opposed to the 6% who thought otherwise.

The results of the study seemed suggested that the students developed a more positive attitude towards science after exposure to the 5E model, which is similar to studies by Aiyelaagbe (1998), who reported a more positive attitude of students after exposing them to self-learning strategy. The positive attitude adopted by the students towards learning science with the use of the 5E model will definitely lead to greater understanding of science topics. This is line with the assertion by Hendrickson (1997), that attitudes are the best predictors for estimation of students' success.

Additionally, some students provided comments on the strengths and weaknesses of the 5E instructional model. For the strengths of the tool, some students explained that the class was 'interesting and fun'. Additionally, they were able to learn at their own pace. Some students wished that they could learn other topics via the same method of instruction. For the weaknesses of the model, some students expressed that the period per lesson was rather short for them to explore all other things. It was also observed that the 5E Model class seemed to be more active and participatory. Compared to the traditional method class was less participatory and interactive.

Table 11. Responses and Corresponding Percentages (%) of Students Attitudes toward using 5E Model Instructional in the Science Classroom

	Agree		*Disagree*	
	Number	Percentage (%)	Number	Percentage (%)
1. I was motivated to be part of the class	32	100	0	0
2. I found the class to be challenging	29	90.6	3	9.4
3. I found the class to be interesting	29	90.6	3	9.4
4. I am very satisfied with my contribution to the class	31	96.9	1	3.1
5. I enjoyed working on items in the in class	31	96.9	1	3.1
6. The class made it easy to learn about diffusion and osmosis	29	90.6	3	9.4
7. I enjoyed working with my classmates	31	96.9	1	3.1
8. We worked together as a team	29	90.6	3	9.4

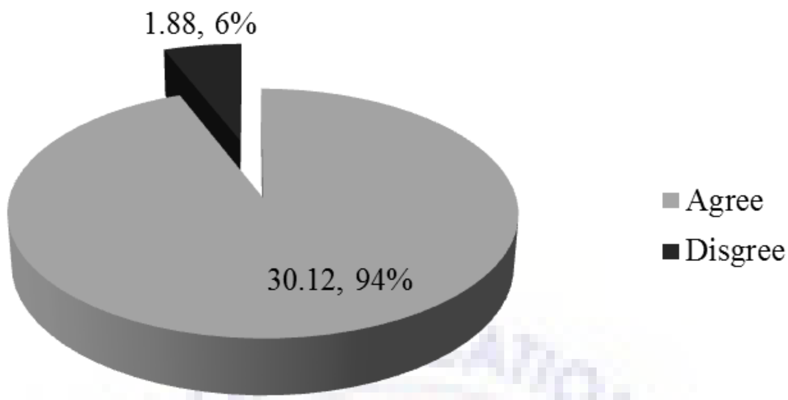

Figure 2. Post-treatment Inquiry-Based Instruction Questionnaire: Questions pertaining to learning preference. Mean percent (%) of student responses, (N=32).

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMMENDATIONS

5.1 Overview

This chapter deals with the summary of findings, conclusions, recommendations and suggestions.

5.2 Summary of Findings

In short, this study showed that the 5E learning cycle model is an effective teaching strategy. On the contrary, traditional instruction does not seem effective in developing students' understanding of diffusion and osmosis concepts. 5E learning cycle model can provide teachers with many insights into how students can learn about and appreciate science. By using this teaching strategy, better acquisition of scientific concepts could be observed. 5E learning cycle model is useful not only in improving achievement, but it they helps students construct their views about science and develop personal thinking abilities.

In spite of improving the students' understanding of diffusion and osmosis some misconceptions still lingered on the minds of students. Furthermore, the 5E model of instruction enabled students to develop more positive attitude towards science as a school subject.

The findings of this study had further established the fact that acceptable methods of instruction are capable of changing students' attitude towards science.

5.3 Conclusion

The findings of this study indicated that both the 5E model and traditional instructional methods showed significant effects on students' achievement as measured with immediate post-test. There was, however, a variation in the levels of achievement between students in the two instructional groups compared. Students in the 5E learning model group were found to score significantly higher marks probably because of the interplay of a higher students' activity during the lessons and social interaction which is a significant feature in the structure of the method.

The major findings of this study indicate that an appropriate method for teaching and learning science could be the 5E model of instruction. This method will, however be very effective only if teachings are trained on the 5E model as a mode of instruction. However, before the adoption of the method as an appropriate instructional strategy, the teachers should be well trained to acquire the skills necessary for its use. The efficient acquisition of the skills necessary for its use by the Science teachers will reduce the limitations associated with the method. The traditional method could still be used to teach very abstract topics to enable students easily acquire knowledge, new information, and explanation of events or things.

Also, it will reduce the frustration students will experience with the other methods when dealing with very novel concepts and, consequently, lead to fewer student misconceptions.

The 5E model group developed a more positive attitude towards science after treatment. If problem-solving instructional strategy, such as the 5E model, could draw many students to offering science in Ghana, it would be necessary for science teachers to adopt this method so as to solve the problem of many students shying away from science at the senior high school level. Teachers should be aware of students' attitudes towards integrated science as a core subject. They must know that attitudes affect the students' achievement and should strive to improve students' attitudes.

5.4 Recommendations

Based on the results of this study, it is recommended that the use of 5E model, a type of instructional strategy that is capable of transforming students from passive receptacles of information into active learners, should be used to teach science. Teachers are exposed to new and emerging techniques that are relevant for the class room and can motivate students, and thereby increase their achievement.

Relevant educational authorities, such as the Ghana Education Service, should also consider providing teachers with adequate professional development, time and incentives to encourage them to integrate inquiry and technology, appropriately, into their instruction.

Teacher educationalists should embrace problem-solving techniques in their various institutions to facilitate the use of the method in to the senior high schools. It would also be essential to organize seminars and workshops for practicing teachers so that the importance and appropriateness of the problem-solving technique for science teaching and learning could be extended.

Further, identification of misconceptions is needed to develop strategies to provide students with the accurate conceptual knowledge required for scientific problem solving.

5.5 Suggestions

Also the following suggestions are made for further researchers:

1) Further research studies can be carried out to investigate the effectiveness of 5E model of instruction approach in understanding science concepts in different schools. So, more accurate results can be obtained and a generalization for Ghana can be provided.
2) A study can be conducted for different levels and different science topics to investigate the effectiveness of the 5E learning cycle model. This study can be conducted with larger sample size in order to obtain more accurate results.
3) Other teaching strategies, such as the concept mapping, and cooperative learning, can be used.

REFERENCES

Aaronson, N. Alonso, J. Burnam, A. Lohr, K.N. Patrick,D.L. Perrin, E. & Stein, R.E. (2002). Assessing health status and quality-of-life instruments: attributes and review criteria. *Quality Life Resources. 11(3)*:193–205.

Abdal-Haqq, I. (1998). *Professional Development Schools, Weighing the Evidence.* Thousands Oaks, CA Corwin Press, Inc.

Abdulsalam, M. (2001). *Recent trends in the teaching of science. Cairo, Egypt: Dar al Western Thought.*

Adams, K. Bevevino, M. & Dengel, J. (1999). Constructivist theory in the classroom. *The Clearing House*, 117-120.

Adesina, A. O., & Akinbobola, A.O. (2005). *The Attitude of Students Towards Part-Time Degree Programme of The Faculty of Education*, Obafemi Awolowo University, Ile-Ife. Journal of Research of Education, 2(1), 1-4.

Aiyelaagbe, G.O. (1998). *The effectiveness of audio, visual and audio-visual self- learning packages in adult learning outcomes in basic literacy skills in ibadan.* Unpublished Ph.D Thesis, University of Ibadan.

Ajaja, O. P. (2013). Which strategy best suits biology teaching? lecturing, concept mapping, cooperative learning or learning cycle? *Electronic Journal of Science Education. Vol. 17,* No. 1.

Akkus, H., Kadayıfçı, H., Atasoy, B. & Geban (2003). Effectiveness of instruction based on the constructivist approach on understanding chemical equilibrium concepts. *Research in Science and Technological Education, 21(2),* 209-227.

Artino, R. (2008). *A brief analysis of research on problem based learning, University of Connecticut. June Eric*, *6*:111-123.

Artun, H., & Costu, B. (2011). *Unveiling primary student-teachers' misconceptions about diffusion and osmosis*. *Journal of Turkish Science Education Volume8, Issue 4,* pp.117-127).

Atkin, J. M., & Karplus, R. (1962). *Discovery or Invention? Science Teacher*, 29(5), 45.

Aydede, M.N., Keserciog˘lu T., & Arabacıog˘lu, S. (2010). Students' opinions regarding the usage of computer technologies in constructivist learning environment. *Int J Human Sci 7(1)*:1114–1123

Baker, D. R. & Piburn, M. D. (1997). *Constructing science in middle and secondary school classrooms.* Copyright by Allyn and Bacon, USA.

Balci, S., Cakiroglu, J., & Tekkaya, C. (2006). Engagement exploration, explanation, extension, and, evaluation (5e) learning cycle and conceptual change text as learning tools. *Biochemistry and Molecular Biology Education, 34 (3),* 199-203.

Baviskar, S. (2009). Essential criteria to characterize constructivist teaching*:* Derived from a review of the literature and applied to five constructivist. *International Journal of Science Education, 31(4): 541-* 550 .

Bennett, J. (2003). *Teaching and learning science* London: Continuum.

Bryce T, & MacMillan K. (2005). Encouraging conceptual change: the use of bridging analogies in the teaching of action–reaction forces and the ‘at rest’ condition in physics. *Int J Sci Educ 6:*737–763

Bybee, R. W. (1997). *Achieving scientific literacy: from purposes to practices*. Portsmouth, NH: Heinemann.

Bybee, R., (2002). ‘*Scientific inquiry, student learning and the science curriculum.’* In R.

Bybee, R. W. Taylor, J. A. Gardner, A. Van Scotter, P., Powell, J. C. Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: origins, effectiveness, and applications*, Colorado Springs: BSCS.

Bybee, R., (2002). ‘*Scientific inquiry, student learning and the science curriculum.’* In R.

Calik, M., & Urey, M.. (2008) Combining different conceptual change methods within 5e model: A sample teaching design of 'cell' concept and its organelles. *Asia-Pacific Forum on Science Learning and Teaching, Volume 9,* Issue 2, Article 12, p.1

Cannela, G. S., & Reif, J. C. (1994). *Teacher Education Quarterly.21 (3)*, 27-38. EJ 498429.

Caprio, M. W. (1994). Easing into constructivism, connecting meaningful learning with student experience. *Journal of College Science Teaching, 23(4),* 210-212.

Cavallo, A. (2003). Students' interpretations of chemical reactions using open-ended questions during the learning cycle. *International Journal of Science Education, 25(5)*: 58-71.

Cavallo, A.M.L. & Laubach, T.A. (2001). Students' science perceptions and enrollment decisions in differing learning cycle classrooms. *Journal of Research In Science Teaching, 38(9),* 1029-1062.

Colburn, A. (2003). *The lingo of learning: 88 education terms every science teacher should know*. Arlington, VA: NSTA Press.

Costu, B. Ayas, A. & Niaz, M. (2010). Promoting conceptual change in students' understanding of evaporation. *Chem Educ Res Pract 11(3):*5–16.

Creswell, J. W. (2003). *Qualitative, quantitative, and mixed methods approaches* (2nd ed.). Thousand Oaks, CA: Sage.

David, W.(2003). Constructivism in the processes of teaching and learning mathematics. paper presented in the third arab conference "systemic approach in teaching and learning", *Ain Shams University, 3 to 4*.

Deka, S. (2010). *Aims of teaching science – a comparative study*. In Articlebase. Retrieved fromhttp://www.articlebase.com/science-articles/aims-of-teaching-cience-a comparative-study-3085292.html.

Diakidoy, I.N, & Kendeou P (2001). Facilitating conceptual change in astronomy: a pomparison of the effectiveness of two instructional approaches. *Learn Instr 11(1):*1–20

Driver, R. Guesne, E. & Tiberghien A. (1985). *Children's ideas in science.* Open University Press, Milton Keynes

Fensham, P.J. (2008). *Science education policy-making: eleven emerging issues.* UNESCO.

Fox, R. (2001). *Constructivism examined.* Oxford Review of Education, 27(1), 23-35.

Fraenkel, J.R, & Wallen N.E. (1996). *How to design and evaluate research in education*, New York: McGraw-Hill.

Francoeur, E. (1997). The forgotten tool: the design and use of molecular models. *Social Studies of Science, 27*, 7–40.

Friedler. Y., Amir, R., & Tamir, P. (1987). High school students' diffi-culties in understanding osmosis. *International Journal of Science Education*, *9*, 541-551. Http://dx.doi.org/10.1080/0950069870090504

Friedrichsen, P. & Pallant, A. (2007). French fries, dialysis tubing & computer models: teaching diffusion & osmosis through inquiry & modeling. American *Biology Teacher, 69(2)*, 22-27.

Gardner, P. L. (1975). Attitude to science: a review. *Studies in Science Education*, *2*, 1- 41.

Garvin-Doxas K., & Klymkowsky MW (2008). Understanding randomness and its impact on student learning: lessons learned from building the biology concept inventory (bci). *CBE Life Sci Educ 7,* 227– 233.

Giere, R. Bickle, J. & Mauldin, R. (2006). *Understanding scientific reasoning.* London: Thomson Learning.

Gilbert, S. (1991). *Model Building and a Definition of Science.* Journal of Research in Science Teaching, 28, 73–79.

Golafshani, N. (2003). Understanding reliability and validity in qualitative research. *The Qualitative Report, 8(4)*, 597-606.

Gordon, M. (2009). Reflections on lessons from practice, educational Studies. *Journal of the American Educational Studies Association, 45(1)*: 39-58

Guzzetti B., Taylor, T.E., Glass, G.V., & Gammas, W.S., (1993). *Promoting Conceptual Hange in Science: A Comparative Meta-Analysis of Instructional Interventions from reading Education*

Halladyna, T. & Shanghnessy, J. (1982). Attitudes towards science: a qualitative synthesis. *Journal of Research in Science Teaching, 66* ***4***: 547-563.

Halloun, I. (2007). Mediated modeling in science education. *Science & Education, 16,* 653-697.

Hand, B. Treagust, D. F. & Vance, K. (1997). Student perceptions of social constructivist classroom. *Science Education, 81*, 561-575.

Hardy, I. Joen A, Moller K, & Stern, E. (2006). Effects of instructional support within constructivist learning environments for elementary school students' understanding of floating and sinking. *J Educ Psychol 98(2):*307–326

Harrison, A. G. (1998). Modeling science lessons: are there better ways to learn with models?. *School Science and Mathematics*, *98(8)*, 420-429.

Hendrickson, A. B. (1997). *Predicting student success with the learning and study strategies 14.* Inventory (LASSI). Unpublished Master's Thesis, Iowa State U University

Howell, D. (2002). *Statistical methods for psychology*. Duxbury. pp. 324–325. ISBN 0-534-37770-X

Hynd, C.R, McWhorter J.Y, Phares V.L, & Suttles C.W., (1994). The role of instructional variables in conceptual change in high school physics topics. *J Res Sci Teach 31(9):*933–946

Hyslop-Margison, & E., Strobel, J. (2011). Constructivism and education: misunderstandings and pedagogical implications. *The Teacher Educator, 43*, 72-86.

Ismat, A. H. (1998). *Constructivism in teacher education: considerations for those who would link practice to theory*. ERIC Digest, (Internet source, available at< www. Ericdigests.org/1999-3/theory.htm>accesed on 22th. Of June 2009>)

Johnstone, A. H. (1991). Why is science difficult to learn? things are seldom what they seem. *Journal of Computer Assisted Learning 7:* 75-83.

Johnstone, A. H., & Mahmond, N. A. (1980). Isolating topics of high perceived difficulty in school biology. *Journal of Biological Education*, *14*, 163-166. H http://dx.doi.org/10.1080/00219266.1980.10668983

Karplus, R., & Their , H. (1967). *a new look at elementary school science*. Chicago: Rand-McNally.

Kaufman, D. (1996). Constructivist-based experiential learning in teacher education. *Action in Teacher Education 18(2),* 40-49. EJ 536 845

Kevin, (2003). Explored the Effect of The Constructivist Learning + Learning Cycle Cycle on Students' Achievement in Studying the Law of Mechanics. *Journal of Science Education, 12(3)*: 65-79.

Khataybeh, A., (2005). *Science education for all*. Al. Amman, Jordan: Maseerah for Publication and Distribution, and Printing.

Kroll, L. R., & LaBosky, V. K. (1996). Practicing what we preach: constructivism in a teacher education program. *Action in Teacher Education 18(2),* 63-72. EJ 536 947

Kruckeberg, R. (2006). A Deweyan perspective on science education: constructivism, experience, and why we learn science. *Science & Education*, *15*, 1-30.

Lawson, A.E. (1995). *Science teaching and the development of thinking.* Belmont, Calif.: Wadsworth.

Lindgren, J. & Bleicher, R. (2005). Learning the learning cycle: the differential effect on elementary preserves teacher. *School Science and Mathematics, 105(2)*: 61-72.

Lord, T. R. (1999). A comparison between traditional and constructivist teaching in environmental science. *Journal of Environmental Education. Vol. 30,* No. 3:22-28.

Lubben, F. Netshisuaulu, T. & Campell, B. (1999). students' use of cultural metaphors and their scientific understandings related to heating. *Science Education, 83,* 761-774.

Marek, E. (1986). Understandings and misunderstandings of biology concepts. *The American Biology Teacher, 48,* 37-40. http://dx.doi.org/10.2307/4448184

Mestre, J. P. (1994). "*Cognitive aspects of learning and teaching science." in teacher enhancement for elementary and secondary science and mathematics: status, issues, and problems,* Washington, DC: National Science Foundation,

Millar, R. (1989). *Doing science: images of science in science education.* London: Falmer Press.

Ministry of Education Jordan. (2006). *The education development conference on developing education towards the knowledge economy*. Amman, Jordan.

Mohapatra, A. (2013). Fostering pre-service teacher trainees' understanding of membrane transport with interactive computer animations. *Creative Education, 4*, 640-645. http://dx.doi.org/10.4236/ce.2013.410092

Morgan, M. & Morrison, M. (Eds.). (1999). *Models as mediators.* Cambridge: Cambridge University Press.

Morrison, G. R., Ross, S. M., & Kemp, J. E. (2004). *Designing effective instruction* (4th ed.). Hoboken, NJ: John Wiley & Sons, Inc.

Musheno, B. V. & Lawson, A. E. (1999). Effects of learning cycle and traditional text on comprehension of science concepts by students at differing reasoning levels. *Journal of Research in Science Teaching, 36 (1)*, 23-37.

National Science Education Standards (1996). Washington, DC: The national Academics Press. National Research Council.

Naylor, S. (1999). Constructivism in classroom: theory into practice. *Journal of Science Teacher Education, 10(2)*, 93-106.

Neo, M. & Neo, T.K. (2009). Engaging students in multimedia-mediated constructivist learning – students' perceptions. *Educational Technology & Society, 12 (2)*, 254–266.

Nitko, A. J. (2001). *Educational Assessment of Students* (3rd ed.). New Jersey: Prentice-Hall Inc.

Odom, A. L. (1995). *Secondary and college biology students' miscon-ceptions about diffusion and osmosis.* The American Biology Teacher, 57, 409-415. http://dx.doi.org/10.2307/4450030

Odom, A.L. & Barrow, L.H. (1993) Freshman Biology Majors' Misconceptions about Diffusion and Osmosis. *In: Paper presented at the annual meeting of the national association for research in science teaching, 9*, Atlanta.

Odom, A. L., & Barrow, L. H. (1995). Development and application of a two-tier diagnostic test measuring college biology students' understanding of diffusion and osmosis after a course of instruction. *Journal of research in Science Teaching*, 32, 45-61. http://dx.doi.org/10.1002/tea.3660320106.

Odom, A.L., & Kelly PV (2001) *Integrating concept mapping and the learning cycle to teach diffusion and osmosis concepts to high school biology students.* Sci Educ 85:615–635

Patel, A., (2012). *Semipermeable Membranes, diffusion, and osmosis inquiry: effective modelingina high school classroom*. Honors College Capstone Experience /Thesis Projects. Paper367. http://digitalcommons.wku.edu/stu_hon_theses/367

Perkins, D.N. (1992). *Smart schools: from training memories to educating minds:* New York: The Free Press.

Perkins, D. N. (1993). *An apple for education: Teaching and learning for understanding* (1993 Elam lecture). Glassboro, New Jersey: The Educational Press Association of America.

Piaget, J. (1970). *Structuralism* (Chaninah Maschler, Trans.). New York: Harper and Row.

Pinarbas, T. Canpolat N. Bayrakc, S. & Geban, O. (2006). An Investigation of effectiveness of conceptual change text-oriented instruction on students' understanding of solution concepts. *Res Sci Educ 36(4):*313–335.

Posner, G.J., Strike K.A., Hewson P.W, & Gertzog W.A. (1982). Accommodation of a scientific conception: toward a theory of conceptual change. *Science Education. 66(2):*211–217. Publications, California.

Qarareh, A. O. (2012). The effect of using the learning cycle method in teaching science on the educational achievement of The Sixth Graders. *International Journal Education Science, 4(2)*: 123-132.

Reigeluth, C.M. (1999). *Instructional-design theories and models*, Volume II: A New Paradigm of Instructional Theory. Mahwah, NJ: Lawrence Erlbaum Assoc.

Richardson, V. (1997). *Constructivist teaching and teacher education: theory and practice.* In V. Richardson (Ed.), Constructivist Teacher Education: Building New Understandings (pp. 3-14). Washington, DC: Falmer Press.

Salta, K., & Tzougraki, C. (2004). *Attitudes toward chemistry among 11th grade students in high schools in greece.* Science Education, *88*(4), 535-547.

Sanger, J. W. & Sanger, J. M. (2001). Fishing out proteins that bind to titin. *J. Cell Biol.154*, 21-24.

Sauro, J. (2011). *Survey items should include a neutral response: Agree, Disagree, Undecided?*. Measuring Usability. Quantitative Usability, Statistics & Six. Retrieved from http://www.measuringusability.com/blog/neutral-option.php

Shields, M. (2006). *Biology inquiries*, San Francisco: Jossey-Bass, Wiley.

Stamp, N., & O'Brien, T. (2005). GK-12 Partnership: A model to advance change in science education. *BioScience, 55 (1),* 70-77.

Stofflett, R. T. (1998). Putting constructivist teaching into practice in undergraduate introductory science. *Electronic Journal of Science Education, Vol. 3, No. 2.* Retrieved from http://unr.edu/homepage/jcannon/ejse/stofflett.html.

Suping, S.M. (2003). *Conceptual change among students in science.* ERIC Digest: ERIC Clearinghouse for Science, Mathematics, and Environmental Education, Columbus, OH. (ED482723).

Tandel, S. H & Pinalben D. G. (2012). "Effectiveness of constructivist 5 „e‟ model" Research Expo, *International Multidisciplinary Research. Journal 2.2:* 76-82. <www.researchjournals.in.>.

Tekkaya, C., Çapa, Y. & Yılmaz, Ö. (2000). Biyoloji Öğretmen Adaylarının Genel Biyoloji Konularındaki Kavram Yanılgıları, Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 18, 140-147.

Tobin, K; and Tippins, D. (1994). *Constructivism as a referent for teaching and learning.* In K. Tobin (ed), controvert in classroom research, Sec. Ed) Buckingham. Open University Press.

Treagust, D. F., Duit, R. and Fraser, B. J. (1996). *improving teaching and learning in science and mathematics.* Teacher College Press: New York, Columbia University.

Tregidgo, D. & Ratcliffe, M. (2000). The use of modeling for improving pupils' learning about cells. *School Science Review, 81,* 53-59.

Trowbridge, L.W., Bybee, R.W. & Powell, J.C. (2000). *Teaching secondary school science.* Upper Saddle River, NJ: Merrill/Prentice Hall.

Tural, G. Akdeniz, A.R. Alev N. (2010). Effect of 5e teaching model on student teachers' understanding of weightlessness. *J Sci Educ Technol 19(5):*470–488

Ultanir, E. (2012). An epistemological glance at the constructivist approach: Constructivist learning in dewey, piaget, and montessori. *International Journal of Instruction, 5*(2), 195-212.

Uno, G. E. (1990). Inquiry in the Classroom, *BioScience, 40(11),* 841-843.

Venkatesh, V. & Morris, M.G. (2000). Why do men ever stop asking for direction? gender social influence and their role in technology acceptance and usage behavior. *Management Information System Quarterly journal. 24(1):* 115-139.

Von Glasersfeld, E. (1993) *Notes for AERA Talk,* Atlanta, April 12th, 1993', *Notes from presentation at the annual meeting of the American Educational Research Association*, Atlanta, GA.

Wandersee, J.H. Mintzes, J.J. Novak J.D. (1994). *Research on alternative conception in science teaching and learning.* Macmillan, New York, pp 177–210

Wang, H. A. Schmidt, (2001). *History, philosophy and sociology of science in science eduation: results from the third international mathematics and science study*. Kluver Academic Publishers. Netherlands.

West African Examination Council. (2008). Chief Examiners Report for May/June SHS Core Subjects.

Westbrook, S. L., & Marek, E. A. (1991). A cross-age study of student understanding of the concept of diffusion. *Journal of Research in Science Teaching, 28,* 649-660. http://dx.doi.org/10.1002/tea.3660280803

Wiseman, D.C. (1999). *Research strategies for education.* New York: Wadsworth Publishing Company.

Yara, O. P. (2009). Students attitude towards mathematics and academic achievement in some selected secondary schools in south western Nigeria. European Journal of Scientific Research, *36(3),* 336-341.

Zuckerman, J. T. (1994). Problem solvers' conceptions about osmosis. *The American Biology Teacher, 56,* 22-25. http://dx.doi.org/10.2307/4449737.

APPENDICES

APPENDIX A

The Diffusion and Osmosis Diagnostic Test

Directions: DO NOT WRITE ON THE ASSESSMENT. This assessment consists of 12 pairs of questions which examine your knowledge of diffusion and osmosis. Each question has two parts: A multiple choice response followed by a multiple choice reason. On the answer sheet provided, please circle one answer from both the response and reason sections of each question.

1a. Suppose there is a large beaker full of clear water and a drop of blue dye is added to the beaker of water. Eventually the water will turn a light blue color. The process responsible for blue dye becoming evenly distributed throughout the water is:

a. osmosis

b. diffusion

c. a reaction between water and dye

1b. The reason for my answer is because:

a. the lack of a membrane means that osmosis and diffusion can not occur.

b. there is movement of particles between regions of different concentrations.

c. the dye separates into small particles and mixes with water.

d. the water moves from one region to another.

The Particulate & Random Nature of Matter

2a. During the process of diffusion, particles will generally move from:

a. high to low concentrations

b. low to high concentrations

2b. The reason for my answer is because:

a. there are too many particles crowded into one area, therefore they move to an area with more room.

b. particles in areas of greater concentration are more likely to bounce toward other areas.

c. the particles tend to move until the two areas are isotonic and then the particles stop moving.

d. there is a greater chance of the particles repelling each other.

3a. As the difference in concentration between two areas increases, the rate

of diffusion:

a. decreases b. increases

3b. The reason for my answer is because:

a. there is less room for the particles to move.

b. if the concentration is high enough, the particles will spread less and the rate will be slowed.

c. the molecules want to spread out.

d. the greater likelihood of random motion into other regions.

4a. A glucose solution can be made more concentrated by:

a. adding more water

b. adding more glucose

4b. The reason for my answer is because:

a. the more water there is, the more glucose it will take to saturate the

solution.

b. concentration means the dissolving of something.

c. it increases the number of dissolved particles.

d. for a solution to be more concentrated one must add more liquid.

5a. If a small amount of sugar is added to a container of water and allowed

to set for a very long period of time without stirring, the sugar molecules will:

a. be more concentrated on the bottom of the container

b. be evenly distributed throughout the container

5b. The reason for my answer is because:

a. there is movement of particles from a high to low concentration.

b. the sugar is heavier than water and will sink.

c. sugar dissolves poorly or not at all in water.

d. there will be more time for settling.

6a. Suppose you add a drop of blue dye to a container of clear water and after several hours the entire container turns light blue. At this time, the molecules of dye:

a. have stopped moving

b. continue to move around randomly

6b. The reason for my answer is because:

a. the entire container is the same color; if they were still moving, the container would be different shades of blue.

b. if the dye molecules stopped, they would settle to the bottom of the container.

c. molecules are always moving.

d. this is a liquid; if it were solid the molecules would stop moving.

Concentration &Tonicity

7a. Suppose there are two large beakers

22with equal amounts of clear water at two different temperatures. Next, a drop of green dye is added to each beaker of water. Eventually the water turns light green (see figure 1).

Which beaker became light green first?

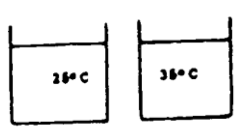

Figure 1

Figure 1A

a. Beaker 1 b. Beaker 2

7b. The reason for my answer is because:

a. the lower temperature breaks down the dye.

b. the dye molecules move faster at higher temperatures.

c. the cold temperature speeds up the molecules.

d. it helps the molecules to expand.

8a. In figure 2, two columns of water are separated by a membrane through which only water can pass. Side 1 contains dye and water, side 2 contains pure water. After two hours, the water level in side 1 will be:

a. higher b. lower c. the same height

8b. The reason for my answer is because:

a. water will move from the hypertonic to hypotonic solution.

b. the concentration of water molecules is less on side 1.

c. water will become isotonic.

d. water moves from low to high concentration.

1. A glucose solution can be made more concentrated by adding more glucose because the more water there is, the more glucose it will take to saturate the solution.

9a. Side 1 is 10% salt solution and side 2 (15% salt solution). Side 1 is ____ to side 2.

a. hypotonic b. hypertonic c. isotonic

9b. The reason for my answer is because: Figure 3

a. water is hypertonic to most things.

b. isotonic means "the same".

c. water moves from a high to a low concentration.

d. there are fewer dissolved particles on side 1.

The Influence of Life Forces on Diffusion& Osmosis

10a. If a freshwater plant cell was placed in a beaker of 25% salt water solution, the central vacuole would:

a. increase in size

b. decrease in size

c. remain the same size

10b. The reason for my answer is because:

a. salt absorbs the water from the central vacuole.

b. water will move from the vacuole to the salt water solution.

c. the salt will enter the vacuole.

d. salt solution outside the cell can not affect the vacuole inside the cell.

11a. Suppose you killed the freshwater plant cell with poison and placed the dead cell in a 25% salt water solution. Osmosis and diffusion would:

a. not occur

b. continue

c. only diffusion would continue

d. only osmosis would continue

11b. The reason for my answer is because:

a. the cell would stop functioning.

b. the cell does not have to be alive.

c. osmosis is not random, while diffusion is a random process.

d. osmosis and diffusion requires cell energy.

12a. All cell membranes are

a. semi-permeable

b. permeable

12b. The reason for my answer is because:

a. they allow some substances to pass.

b. they allow some substances to enter, but they prevent any substance from leaving.

c. the membrane requires nutrients to live.

d. they allow ALL nutrients to pass.

APPENDIX B **Sample Marked Scripts**

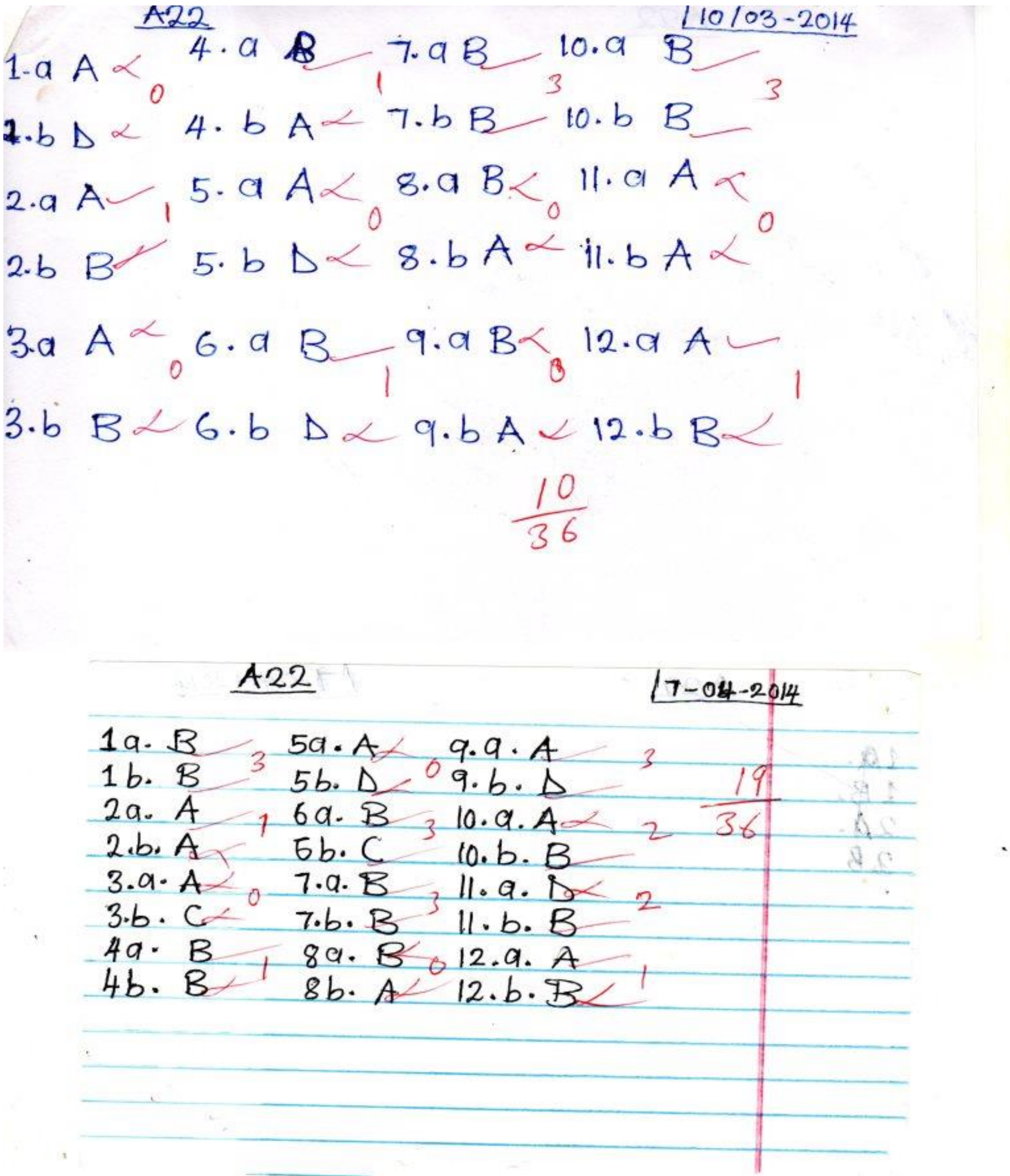
A22 10/03-2014
1.a A 4.a B 7.a B 10.a B
1.b D 4.b A 7.b B 10.b B
2.a A 5.a A 8.a B 11.a A
2.b B 5.b D 8.b A 11.b A
3.a A 6.a B 9.a B 12.a A
3.b B 6.b D 9.b A 12.b B
10/36
A22 17-04-2014
1a. B 5a. A 9.a. A
1b. B 5b. D 9.b. D
2a. A 6a. B 10.a. A
2.b. A 6b. C 10.b. B
3.a. A 7.a. B 11.a. D
3.b. C 7.b. B 11.b. B
4a. B 8a. B 12.a. A
4b. B 8b. A 12.b. B
19/36

Figure 1B. Pre-test and Post-test of student A22 (control group)

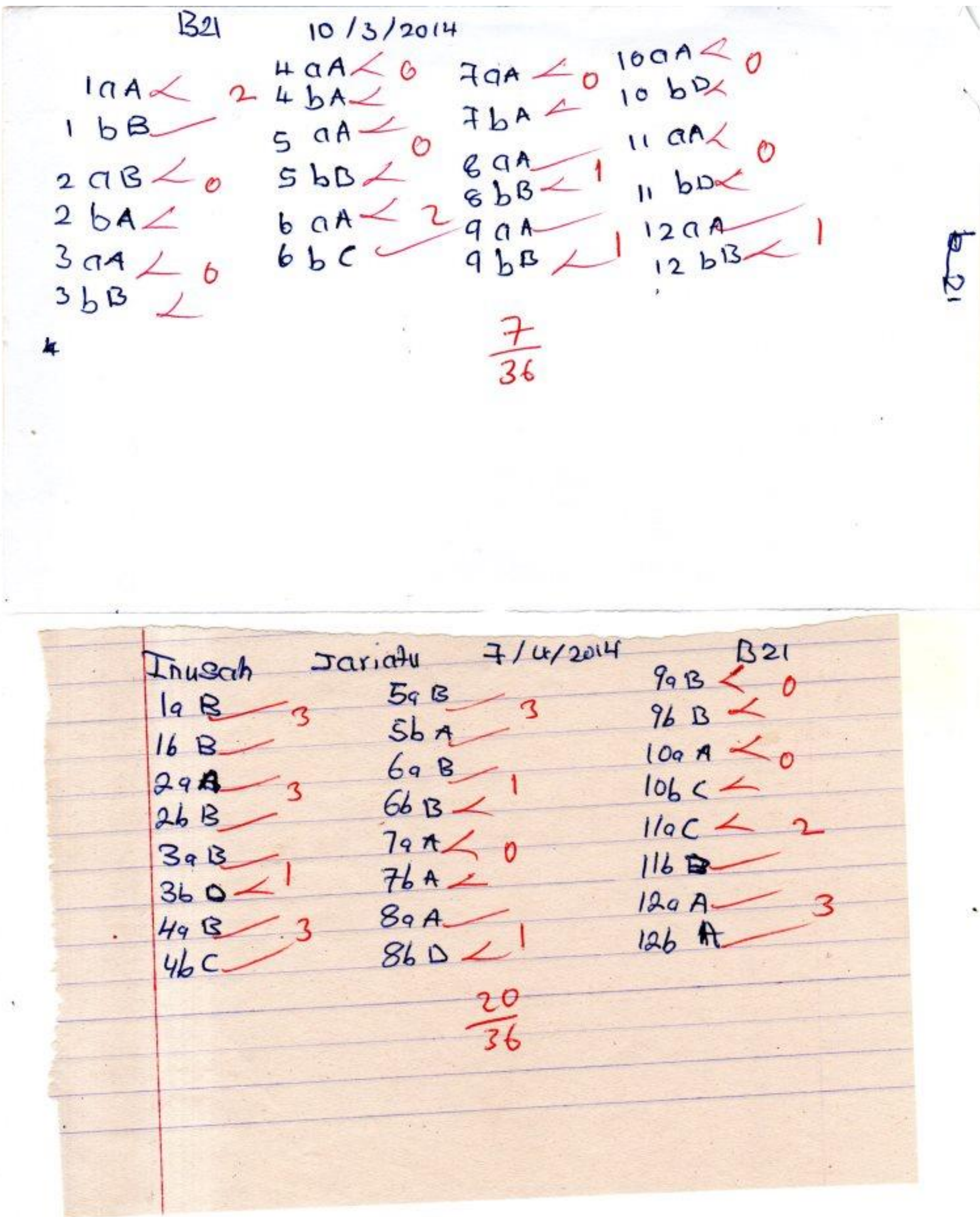

Figure 2B. Pre-test and post-test of student B21 (experimental group)

APPENDIX C

5E Model Based Instruction Questionnaire

Participation in this research is voluntary and participation or non-participation will not affect your grades or class standing in any way. The purpose of this questionnaire is to provide you with the opportunity to share your opinion on inquiry based instruction on. Check *Agree* or *Disagree* for each statement, then provide further explanation for your selection in the *Comments* column. Please answer each question honestly. Your answers will be anonymous. Agree

	Agree	Disagree	Comments
1. I was motivated to be part of the class			
2. I found the class to be challenging			
3. I found the class to be interesting			
4. I am very satisfied with my contribution to the class			
5. I enjoyed working items in the class			
6. The class made it easy to learn about diffusion and osmosis			
7. I enjoyed working with my classmates			
8. We worked together as a team			
Is there anything else you would like to tell me?			

(Adapted from Neo and Neo, 2009)

APPENDIX D

Table 1D. Propositional Knowledge Statements Required for Understanding Diffusion and Osmosis

1. All particles are in constant motion.
2. Diffusion involves the movement of particles.
3. Diffusion results from the random motion and/or collisions of particles (ions or molecules).
4. Diffusion is the net movement of particles as a result of a concentration gradient.
5. Concentration is the number of particles per unit volume.
6. Concentration gradient is a difference in concentration of a substance across a space.
7. Diffusion is the net movement of particles from an area of high concentration to an area of low concentration.
8. Diffusion continues until the particles become uniformly distributed in the medium in which they are dissolved.
9. Diffusion rate increases as temperature increases.
10. Temperature increases motion and/or particle collisions.
11. Diffusion rate increases as the concentration gradient increases.
12. Increased concentration increases particle collisions.
13. Diffusion occurs in living and nonliving systems.
14. Osmosis is the diffusion of water across a semipermeable membrane.
15. Tonicity refers to the relative concentration of particles on either side of a semipermeable membrane.
16. A hypotonic solution has fewer dissolved particles relative to the other side of the membrane.
17. A hypertonic solution has more dissolved particles relative to the other side of the membrane.
18. An isotonic solution has an equal number of dissolved particles on both sides of the membrane.
19. Osmosis is the net movement of water (solvent) across a semipermeable membrane from a hypotonic solution to a hypertonic solution.
20. Osmosis occurs in living and nonliving systems.
21. A semipermeable membrane is a membrane that selectively allows the movement of some substances across the membrane while blocking the movement of others.
22. Cell membranes are semipermeable.

(Adopted from Odom and Barrow, 1995)

APPENDIX E

Table 1E. Item number, propositional knowledge statements and topics areas tested by Diffusion and Osmosis Diagnostic Test (DODT).

Item Number	Topic area	Propositional statements
1	The process of diffusion	2, 4
2	The particulate and random nature of matter	2, 4, 5, 6, 7, 12
3	The particulate and random nature of matter	2, 3, 4, 11, 12
4	Concentration and tonicity	5
5	The process of diffusion	4, 5, 6, 8
6	The particulate and random nature of matter	1, 2, 3, 8
7	Kinetic energy of matter	9, 10
8	The process of diffusion	14, 19, 21
9	Concentration and tonicity	15, 16, 17, 18
10	The process of osmosis	14, 19, 22
11	The influence of life forces on diffusion and osmosis	13, 20
12	Membranes	21, 22

(Adopted from Odom and Barrow, 1995)