Science and Mathematics Education Centre

Pre-service Science Teachers' Understanding of the Concepts Relating to Diffusion, Osmosis, and the Particulate Nature of Matter and Their Attitudes Towards Science

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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Date: 8.12.2011

ABSTRACT

This study investigated understanding of diffusion, osmosis and particle theory of matter concepts among pre-service science teachers in Saudi Arabia using a 17-item two-tier multiple choice diagnostic test that was adapted from two previously developed instruments in the research literature. The participants were 192 pre-service science teachers from 15 Saudi Arabian teachers' colleges who were in the second and third years of a 4-year course leading to a bachelor degree. In addition, the study evaluated the pre-service science teachers' attitudes to science using 30 items from the Test of Science-Related Attitudes (TOSRA) questionnaire. Analyses of their responses indicated that the total score for the eight diffusion and osmosis items ranged from 3 to 8, while the total score for the nine particle theory items ranged from 3 to 7. The correct responses to the osmosis and diffusion items and those to the particle theory items were significantly correlated (Pearson correlation = 0.42, $p < 0.01$).

On the whole, correct responses to both tiers of the items of the diagnostic test were lower than those for the first tier only. For example, for the eight items on osmosis and diffusion, 60.4% to 93.4% of pre-service teachers provided correct responses to the first tier, whereas only 44.9% to 70.5% provided correct responses to both tiers. As for the nine items on the particle theory, 51.5% to 88.6% provided correct responses to the first tier, whereas only 41.0% to 63.0% provided correct responses to both tiers of the items. Pre-service teachers' attitudes to science were evaluated using three dimensions of the TOSRA, namely, Adoption of Scientific Attitudes, Enjoyment of Science Lessons, and Attitude to Scientific Inquiry. The mean scores of these three dimensions of the TOSRA were highly correlated to each other, the Pearson correlations ranging from 0.44 to 0.49 with $p < 0.01$ in each case.

Several alternative conceptions—that were held by more than 10% of the pre-service teachers—were identified in this study. For osmosis and diffusion, these alternative conceptions included misconceptions about the difference between the two concepts, the process of osmosis itself, understanding of a semi-permeable membrane, and the effect of temperature on solubility. In the case of the particle theory, the alternative conceptions that were identified were related to understanding of changes of state, the process of dissolution, confusion between macroscopic and

submicroscopic properties of substances, particle arrangement in the three states of matter, and diffusion in gases and liquids. Interviews with the pre-service teachers provided useful insights into their understanding of the concepts that were evaluated by the diagnostic test as well as about their confidence in teaching these concepts on completing their studies.

The author recognised that there is need for developing a curriculum that will help pre-service teachers in understanding the basic concepts related to diffusion, osmosis and the particulate nature of matter. At the same time, classroom instruction in teachers' colleges in Saudi Arabia should be more relevant to student teachers' everyday experience in order that they may adopt more positive attitudes towards science.

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CHAPTER ONE

INTRODUCTION

1.1 Statement of the Problem

It is widely recognized all over the world that science is in the frontier of any nation's progress; thus science education should be an important component of any school curriculum. One of the aims of science education is the development of scientific literacy for all. A scientifically literate person, "should develop an understanding of all concepts, principles, theories, and processes of science" (Abd-El-Khalick & BouJaoude, 1997, p.673). Despite the introduction of several programs to enhance the quality of science education—in Australia, the National Assessment Program Science Literacy provided by Education Services Australia (2009), and the Primary Literacy Program by the Department of Education and Training Western Australia (2010) serve as examples—the status of scientific literacy among students is generally declining worldwide (PISA, 2006; Unaldi & Bilgi, 2008).

Biology and chemistry are branches of science of relative importance as these disciplines provide the foundation for all medical courses. However, studies have shown that students have difficulty in the study of biology and chemistry due to the necessity of understanding numerous concepts (Singer, Wu, & Tal, 2003). As a consequence, learners treat these subjects with boredom, resulting in learning that is not effective.

Diffusion, osmosis and the particulate nature of matter are among the most investigated concepts in science (Yager, Tamir, & Kellerman, 1994). Science educators agree that these concepts hold the keys to understanding several phenomena in middle and high school science curricula (El-Sayed, 1987; Singer et al., 2003; Yezierski & Birk, 2006; Yeany & Miller, 1983).

It is therefore important that pre-service teachers acquire a thorough understanding of these concepts so that any alternative conceptions that they may hold are not passed on to their students when they begin their teaching careers.

1.2 Context of the Study

Presently, in the Saudi Arabian educational system, schools and higher education institutions aim to provide learners with the necessary skills and concepts that will help them understand scientific phenomena and basic science concepts in a rapidly advancing technological world. In order to achieve this goal, the teacher plays an important role in the successful teaching and learning process by directing and guiding the students. It is the teacher who implements all educational innovations because it is he or she who comes in direct contact with the students. The success of the teaching of science or any other subject area lies with the teacher. With this in mind, Teacher Education Colleges in Saudi Arabia aspire to achieve teaching excellence through a progressive program of pre-service teacher education. In recognizing the importance of science education in Saudi Arabia, the curriculum has been developed based on the following principles of benchmarks set in the United States, specifically, the National Science Education Standards (NSES, 2000), namely, (1) Science is for all students; (2) Learning is an active process; (3) Schools reflect the intellectual and cultural traditions that characterize the practices of contemporary science; and (4) Improving science education is part of systematic reform.

Thus, we can deduce that these principles will have a profound impact on the knowledge, attitudes and/or practices of pre-service science teachers. Despite planning for improvement in delivery and assessment practices in education in Saudi Arabia, the status of science education has been gradually declining (Radwan, 1991; Al-hurr & Ar-rumi, 2002; Bingimlas, 2009). It is widely acknowledged that in the teaching and learning process the teacher and the learners encounter a range of generic problems. For example, Bingilmas (2009) writes about the barriers to knowledge and skills development that Saudi Arabian pre-service science teachers face.

For the teachers, the problems might be the result of poor foundations in their scientific knowledge and skills. This lack of competence may have arisen from an inadequate preparation in the profession of teaching science. These problems appear to be leading towards ongoing unsatisfactory teacher performance, and more alarmingly, limited learning opportunities for the students (Radwan, 1991; Al-hurr & Ar-rumi, 2002; Bingimlas, 2009; Patrick J. Garnett, Garnett, & Hackling, 1995).

1.3 Rationale

Deficiencies in Saudi Arabian science instruction are of concern (Radwan, 1991). Al-hurr and Ar-rumi (2002) reported that there is evidence of defeatism in education in many of the Gulf Countries. In a study of biology teachers in Egypt, Motaweaa (1995) found that there were large discrepancies between the intended and the actual knowledge held by teachers. Al-hurr and Ar-rumi (2002) further inferred that the teaching staff are not actively improving learning outcomes but instead are following routines. Hassan (1987, p. 23) found that biology teachers, in particular in the Gulf, can be of "low performance".

To make matters worse, there is evidence that teachers in the region believe that the achievement ability of students is innate and hence pre-determined (Al-hurr & Ar-rumi, 2002). With this point-of-view, they consider that improving teaching is a futile effort. The reported existence of some of these beliefs, views, and attitudes suggests that there is a need to better understand the teachers' attitudes towards science. These views include areas such as the acceptance of scientific inquiry as a way of thought, the adoption of scientific attitudes, and the enjoyment of science learning experiences. It is reported that if teachers of science do not hold positive attitudes towards their discipline, they will not be able to best facilitate student achievement of learning outcomes (Fraser, 1977a).

Furthermore, ineffective assessment procedures, incongruent with improving learning outcomes, are readily observed (Al-hurr & Ar-rumi, 2002). The problem is universal. As Black (2001) comments, "the collection of marks to fill up records is given greater priority than the analysis of pupils' work to discern learning needs" (p.4).

There is a dearth of studies on the use of diagnostic tests in the Gulf region (Al-hurr & Ar-rumi, 2002). One study in Qatar with 698 male and female Year 2 students found that students were still overwhelmingly being tested using traditional assessment forms. In this study, Al-hurr and Ar-rumi (2002) concluded that teachers were slow to adapt to new assessment procedures.

Therefore, the move from traditional to more contemporary forms of assessment is taking place very slowly. Importantly, traditional assessment practices have restricted teachers' innovation in the classroom. At the moment, teachers are still rewarded for using methodologies which focus on memorization and recall. As the norm is the traditional pass or fail in tests where memorization is important, the students themselves adopt study approaches which are simply a means to an end and do not make an effort at mastering the concepts (Fleming, 1998). In an attempt to address this situation, this study investigates the administration of a diagnostic test in science by pre-service science teachers who will be charged with the responsibility of educating the next generation of Saudi students. Furthermore, with a focus on biology education, the study to examine attitudes towards science teaching of a sample of pre-service science teachers.

The change away from traditional assessment procedures also is the focus of this study. Traditionally, students have been asked to respond to questions generally isolated from the other assessment items (Wiggins & McTighe, 1998). In contrast, modern assessment stresses the need for holistic approaches (Wiggins & McTighe, 1998). The Programme for International Student Assessment (PISA) conducted by the Organization for Economic Cooperation and Development (OECD) recommends that assessment items be presented within a context (Wiggins & McTighe, 1998). Therefore, the design of the assessment items presents a context that frames the question. The first part of each question requires a content response to a question within a context. This is done in the first part, that is, the first tier of each question. The second tier asks participants to justify their responses. The importance of the second tier is mentioned by Wiggins and McTighe (1998) who found that the best assessment items are those that "require an explanation or defence of the answer, given the methods used" (p.14).

1.4 Purpose of the study and research questions

This research aimed to determine the understanding of osmosis, diffusion and particulate theory concepts among pre-service science teachers in Saudi Arabia using modified versions of the two-tier multiple choice diagnostic instrument on osmosis and diffusion (Odom & Barrow, 1995) and the Test of Science-Related Attitudes, TOSRA (Fraser,1981). Specifically, this study sought to answer the following research questions:

Research question 1: What is the nature of diffusion and osmosis conceptions among Saudi Arabian pre-service science teachers?

Research question 2: What is the nature of the particle theory of matter conceptions among Saudi Arabian pre-service science teachers?

Research question 3: What are the relationships between Saudi Arabian pre-service science teachers' conceptions of diffusion and osmosis and those of the particulate nature of matter?

Research question 4: What are Saudi Arabian pre-service science teachers' attitudes towards science?

Research question 5: What are Saudi Arabia pre-service science teachers' perceptions of the data collection procedure?

1.5 Significance of the Study

Diffusion and osmosis are topics in the science curriculum of the Bachelor of Education program in Saudi Arabian science teacher-training institutions. Knowledge of both diffusion and osmosis is an important pre-requisite for any prospective science teacher of biology. Furthermore, the effective implementation of diagnostic tests and attitude tests such as the TOSRA (Fraser, 1981) is an important stepping stone to help improve teaching and learning in the Gulf States. It is expected that this research will go some way towards providing data to document how the teaching and learning of diffusion and osmosis and the particulate nature of matter is currently being taught to and learned by Saudi Arabian pre-service teachers.

For pre-service science teachers, this study can provide insight into how they perceive particular concepts in relevant conceptual domains and what attitudes they hold towards learning science. The diagnostic test will provide answers into the scientifically acceptable as well as inappropriate conceptions about osmosis and diffusion and the particle theory of matter that are held by this group of pre-service teachers. If a teacher of science at any level holds misconceptions about these concepts, then the students, whether pre-service teachers or otherwise, of this instructor are surely disadvantaged. Therefore, this study will provide pre-service teachers with useful feedback about their own misconceptions (or alternative conceptions) about diffusion and osmosis and the particulate nature of matter concepts. For the pre-service teachers' future, this study holds possibilities of enhanced levels of understanding resulting from improved instruction.

1.6 Limitations of the Study

The most severe limitation is the relatively small sample of 193 pre-service science teachers who were involved in the study. Nevertheless, it is considered to be representative of the population of pre-service science teachers from Saudi Arabia. Extensive geographic distance between universities in Saudi Arabia made gathering a larger sample in this regard impractical.

1.7 Methodology

In this study, the two-tier multiple choice diagnostic test on diffusion and osmosis (Odom & Barrow, 1995) and the particle theory of matter (Othman, Treagust & Chandrasegran, 2008) were modified such that 17 items were used to evaluate pre-service science teachers' conceptions of osmosis and diffusion and the particulate nature of matter relating to the Saudi Arabian Science curriculum.

The Test of Science-Related Attitudes (TOSRA) (Fraser, 1977b), involves a Likert-type (Likert, 1932) questionnaire to identify respondents' attitudes towards science. While the TOSRA has seven scales, only three scales that were deemed relevant to the prescribed research objectives were used in this study, Attitude to Scientific Inquiry, Adoption of Scientific Attitudes and the Enjoyment of Science Lessons.

1.7.1 Data sources

Twenty pre-service science teachers were first involved in a pilot study to ascertain the reliability of the items in the instrument. Subsequently, a sample of 193 teachers was involved in the main study. The instrument consisting of 17 items was translated from English into Arabic and then back translated to ensure that the same original variables were being measured.

1.7.2 Data analysis

The data collected by the questionnaire were analyzed using the Statistical Package for Social Science (SPSS Version 17.0). Completed questionnaires were coded and the data loaded to SPSS – PC for statistical analysis. Data analysis, frequencies, means and standard deviations were calculated for all items. Correlation coefficients between the scales were used to determine their relationships with each other.

1.8 Overview of the Study

After discussing the background, purpose of the study, rationale and contextual significance of the study in Chapter 1, Chapter 2 presents a review of the literature related to the research on learning theories, the TOSRA, formative assessments and diagnostic assessments. Chapter 3 provides a more detailed description of the methodology used to help identify the alternative conceptions of the teachers. This procedure involved a qualitative and quantitative approach to analyze the alternative conceptions among the pre-service science teachers. In Chapter 4, the pilot study is described to enable me to determine the validity of the instruments. Chapter 5 includes the presentation of data which were interpreted and analyzed on the basis of the problem raised. Chapter 6 presents the analyses and results. Chapter 7 contains a summary, conclusions and recommendation.

The main purpose of this study was to determine the pre-service science teachers' understanding, as well as to identify alternative conceptions, of diffusion, osmosis and the particulate nature of matter. In addition, the study sought to document the teachers' attitudes towards science. The findings may be used to enable teachers and curriculum writers to be aware of student alternative conceptions so that they can develop appropriate teaching strategies and materials to help students better understand these concepts.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews the literature relevant to pre-service teachers' misconceptions in science and is divided into an introduction, six content sections and a chapter summary that are directly related to the research objectives. Understanding the theories of learning that are essential to this study is considered in Section 2.2. As knowledge about the effectiveness of the process of teaching and learning requires understanding of objective assessment methods, the second section examines the main features of formative and summative assessment. Section 2.3 expands on the second and discusses the implications of utilising two-tier tests as assessment tools in educational practice and research.

The particulate nature of matter is a key concept in the physical and biological sciences. Understanding the concepts of osmosis and diffusion, particularly in the life sciences, requires understanding of particle theory concepts. As students have difficulty with all of these concepts, the significance of diffusion, osmosis and the particulate nature of matter are reviewed in the fourth section with discussion of students' difficulties with these concepts. Often these difficulties arise due to alternative conceptions that students hold about these concepts. The fifth section considers the process of students forming their own conceptions that differ from scientifically acceptable conceptions, and the impacts of these on learning.

Science is playing a growing role in Saudi Arabian society; and to maximise the potential benefits of science and technology, it is important that positive attitudes to these be engendered in students. Thus, the final sections of the literature review examine how students' attitudes towards science can be best evaluated.

2.2 Learning

2.2.1 Theories of Learning

Theories of learning are helpful for understanding how students learn science concepts so that appropriate instructional strategies can be developed and relevant materials provided to help address students' learning difficulties. According to Duit and Treagust (1995), science teaching from primary school to university often fails in advancing students' understanding of science. Students may fully understand scientific terminology and, for instance, "might be able to provide the names of animals and plants, to write down the Schrödinger equation without any difficulties, or to provide key examples when presented with formulas" (p. 46) but often with no in-depth understanding of the knowledge acquired.

For many years, philosophers and scientists have been researching how people gain knowledge and obtain meaning. Two early theories, empiricism postulated by Aristotle, and nativism or apriorism postulated by Plato and later by Chomsky, were advanced to describe the acquisition of knowledge by human beings (Lawson, 1994). Lawson (1994) provided a different view of empiricism stating that people can gain knowledge from their keen observations of the world. He believes that knowledge acquisition "appears to involve a complex interaction among sensory impressions, properties of the organism's developing brain and the organism's behaviour in a dynamic and changing environment" (p. 132).

2.2.2 Process of Knowledge Acquisition

The process of knowledge acquisition has been described by different theoretical models. Piaget (1977) proposed that at different chronological ages learners move through different stages of cognitive development. He also believed that because of these stages learning can be managed successfully. According to Piaget, it is not necessary to wait until the learners' mentality is fully developed to acquire difficult knowledge but this might in some circumstances result in mental disequilibrium possibly leading to mental reorganization or equilibration. Ausubel (1968) defined meaningful learning as relating to a learning task in a "non-arbitrary, substantive (non-verbatim) fashion to what the learner already knows" (p. 24). The learning task should be incorporated into the learner's cognitive structure by modification, qualification and elaboration of the existing knowledge that the learner has acquired. To make the learning task meaningful, the learner needs prior knowledge of the topic so that he or she can make sense of the task and give a proper explanation of it. Additionally, the learner must learn meaningfully from the beginning. Whether or not a task is meaningful depends mostly on the adequacy of a learner's applicable prior knowledge (Novak, 1976). Meaningful learning is important to Ausubel (1968) who described it as it as the "human mechanism par excellence for acquiring and storing the vast quantity of ideas and information represented by any field of knowledge" (p. 58). There is a great difference between meaningful learning and rote learning which Ausubel described as "purely arbitrary associations" (p. 24).

Learners have to be active participants in acquiring meaning and knowledge but not inactive recipients. No one but the learner is responsible for his or her own learning (Novak, 1988). Learners must choose to learn by themselves and they should gain meaning from their own learning tasks (Ausubel, 1968). Discussion with peers encourages knowledge construction because it provides a forum in which previously implicit ideas can be made explicit and available for reflection. Discussion also provides the opportunity to build on each others' ideas in order to arrive at a more acceptable solution.

The significant effects of a learner's knowledge must of course be potentially meaningful in the first instance. This means learners must be able to relate to what they already know (Driver, 1995; Duit, 1995; Johnstone, 1999; Osborne & Wittrock, 1985, Pintrich, Marx, & Boyle, 1993). The various aspects of learning a task influence the learner's knowledge, retrieve information from the memory and generate the links between the tasks. Osborne and Wittrock (1985) hold the same view as Novak (1976) that learners must accept responsibility for their own learning as meaning acquisition requires active construction.

However the circumstances of learners vary. Osborne and Wittrock (1985) stated "the view that success or failure in making better sense of experience, and in understanding the ideas of others, is dependent on the people" (p. 76). The high level of demands on students may result in their resistance to constructive learning "to engage with the ideas in a deep and sustained manner" (Duit & Confrey, 1996, p. 85). On the other hand, the learner's task might be beyond his or her cognitive maturity and ability because it is too difficult and theoretical (Adey, 1992). Students feel more comfortable being led to the ‘correct answer’ instead of exploring ideas (Duit, 1995; Hogan, 1999).

Children develop theories and explanations for phenomena they encounter in their everyday life experiences (Driver, Squires, Rushworth, & Wood-Robinson, 1994; Novak, 1988; Osborne & Wittrock, 1985). Knowledge built up in the students’ domains of experiences is resistant to change because, to them, this knowledge is coherent, sensible and fits into their cognitive structures. However some of these concepts differ from those of experts. For instance, according to Osborne and Wittrock, (1985) children are limited in their ability to explain specific events by factors such as their egocentricity, their human centredness, their limited ability with language, their limited experiences and their interest in “mini theories” (p. 69). Novak (1988) believed that the epistemological commitments of students which influence their learning, thinking, feeling and acting are integrated. He stated that a student “with a constructive commitment also shows capacity for modifying wrong or inadequate conceptions” also, “there is a pattern to the feelings expressed, with negative feelings associated with cognitive involvement in essentially rote learning and positive feelings expressed when involvement is meaningful” (p. 95).

Further, Hewson (1996) described a learner’s acceptance as a measure of the status of or their preference for an idea, new or old; the higher the status the more likely the concept is held and is based on the conditions of intelligibility, plausibility, and fruitfulness (Posner et al. 1982). Learning as conceptual change is portrayed as “a process in which a person changes his/her conceptions by capturing new conceptions, restructuring existing conceptions, or exchanging existing conceptions for new conceptions” (Hewson, 1996, p. 132). The learner will not accept the new conception without encountering conflict within existing conceptions, that is, the learner must first have reason to be dissatisfied with his or her existing conceptions. Chi, Slotta, and de Leeuw (1994) described entities of the earth as belonging to different ontological categories such as matter, processes and mental states. Difficulties in learning occur when concepts belong in different ontological categories. If the student’s conception and scientific concept are ontologically compatible, for example, both belong to the matter category, then conceptual changes are easy. Learning is more difficult if the concepts are ontologically distinct; learners must alternate between two conceptual categories in trying to understand a new science concept.

2.2.3 Social and Cultural Influences on Learning

Social aspects of the learning environment and learners' motivational beliefs about themselves were highlighted by Pintrich et al. (1993) and Hogan (2000). Most phenomena are accepted as they are by the students; students think they do not need to give a phenomenon their own thinking and imagination. This belief is also echoed by Johnstone, Hogg, MacGuire, and Raja (1997). Students should be inspired in the first instance so that they can focus on, and pay attention to, a particular scientific concept before a teacher can motivate them to study or examine the concept. Most scientific concepts are perceived as complex by students and this perception can affect students' learning about specific scientific concepts (Huddle, White, & Rogers, 2000).

In studying learning, learners' values, efficacy beliefs, goal orientation, and control beliefs should not be neglected. To interpret learning from ontological (Chi et al., 1994), social/affective (Pintrich et al., 1993), and epistemological (Posner et al., 1982) viewpoints, the application of multidimensional constructions was suggested by Tyson, Venville, Harrison, and Treagust (1997). This multidimensional framework gives a clearer picture of how students perceive "the nature of the thing to be studied" (Tyson et al., 1997, p. 398), "his or her own knowledge of the thing to be studied [and] the social/affective conditions necessary for conceptual change to occur" (p. 399). The framework was used by Venville and Treagust (1998) to explore Grade 10 students' conception of genes during a ten-week genetics course. The various perspectives contributed valuable insights into the process of conceptual change which occurred in the students. During the course the researchers found that there was much overlap and interaction between the ontological and epistemological aspects of learning.

The difficulties associated with learning scientific concepts mean children need to be initiated into the culture and social institutions of science because they cannot discover these on their own to make sense of what they are learning in science (Driver, 1995; Driver et al., 1994; Osborne, 1996). The development of a child is a "balance of aspects of self-development and guidance" (Duit, 1995, p.274). Teachers need to provide the appropriate experience by introducing the concepts, theories, models, procedures and language used by the scientific community. For instance, children up to the age of five and adults with no formal schooling cannot understand the everyday concepts of solids and liquids. This significant fact was highlighted to the world of science by Stavy (1994). Rop (1999) highlighted a dark aspect of the cultural and social aspects of school science learning in the United States where scientific knowledge has become “information or skills to be repeated or demonstrated in assignments and tests” (p. 228). Put simply, to obtain good results in examinations teachers present and student’s rote learn, while critical understanding takes a back seat (Barrow, 1991; Roth & Roychoudhury, 1994).

There are similarities between the ideas of science constructed by students and the development of scientific theories and ideas in the wider community (Driver et al, 1994). Phenomena are the constructions of individuals (Driver, 1995; Duit & Treagust, 1995). However, before being accepted, any kind of scientific idea or theory needs to be communicated, discussed and examined thoroughly, resulting “in the scientific community sharing a view of the world involving concepts, models, conventions, and procedures” (Driver et al., 1994, p. 6). Thus a phenomenon becomes accepted by a group rather than just by an individual. Science should be seen as being “fallible, self-correcting, and progressive, rather than infallible, always correct, and conservative” (Eltinge & Roberts, 1993, p. 66) and teachers should highlight how scientific ideas are developed and evaluated so that students “can appreciate the ‘provisional’ nature of science ideas and gain confidence in trying and testing ideas” (Driver et al., 1994, p. 7). In the eyes of teachers and students, transferring all the accumulated facts in memory is learning because they are “naïve realists in that they view science and mathematics knowledge as a faithful copy of the ‘world outside’ and not as tentative human construction” (Treagust, Duit & Fraser, 1996, p. 2). For this reason, the constructive meaning of a lesson may not be accepted by the students, and the teachers might continue to ‘fill their students’ ‘blank minds’ with non-constructive meanings from the lesson without providing the actual knowledge (Gilbert, Osborne, & Fensham, 1982).

2.3 Formative and Summative Assessments

2.3.1 International Impetus for Better Educational Standards

Particularly in numeracy, science, and literacy, there are marked attempts to raise educational standards. Part of the problem relates to the low participation rates by students in studying science. This issue is expanded on by Treagust (2006, p. 7).

It is of great concern in several countries that there is continuing low participation rate of students taking science in higher levels of secondary school education, including among Years 11 and 12 students in Australia. In particular, enrolments are on the decline in the more conceptually demanding calculus-based options that lead to acceptance in university science and engineering courses. There are even more dramatic enrolment declines in other countries such as Great Britain and France. Indeed, the success, and even the continuation, of science programs at university are dependent on foundational improvements in science education in secondary schools.

This push has occurred across the board from early childhood education to secondary school (Hill, 2002). In order to better understand educational performance in terms of learning outcomes achieved, a number of instruments including those from the Trends in Mathematics and Science Study (TIMSS) (1999), and the Programme for International Student Assessment (PISA) (2000) have been developed. After a specific unit of learning or schooling years, the international and national assessments measure student achievement in these summative assessments.

2.3.2 Constructivist View of Assessment

The belief that the conceptions students hold before entering the classroom greatly influences the ideas that the student takes out of the learning experience is the foundation of constructivism (Ausubel, 1968; Chandrasegaran, Treagust, & Mocerino, 2007). Constructivism accepts as true that students' conceptions about science are often dominated by their prior ideas, that is, their pre-instructional knowledge, rather than what the teacher presents to them during the lesson (Treagust, 2006). Students' understanding of essential concepts is the focus of assessment in the constructivist view. The accountability of assessments has increasingly become a topic of debate for departments of education and school boards. Focusing at the school level, high-stakes testing has become the focus of assessments. However, while this focus on high-stakes testing can illuminate potential learning issues, such testing does not contribute directly to student learning (Ciofalo & Wylie, 2006). This type of assessment measures the level of achievement that is reached by a student and is known as summative assessment. An example of one of these in the USA is the National Certificate of Educational Achievement (NCEA) which is awarded for school-based assessment in a number of settings. Certificates of this style consist of external achievement standards as well as internal achievement standards.

2.3.3 Formative Assessment: The Role of Feedback

An integral part of the teaching-learning process is a framework for improving learning using formative assessment. Feedback, identified as information on whether or not the learning is successful, is the key element of formative assessment (Sadler, 1988). Feedback that occurs in a supportive learning environment has an optimum effect providing feedback loops for the teacher and the learner (Sadler, 1988). Summative assessments are the assessments of learning; however, formative assessment is for improving learning and has a diagnostic function. Feedback is one of the functions of formative assessment that is used to address areas of misunderstanding and can be used to modify the teaching-learning program. On instructional grounds, teachers must be able to justify assessment strategy uses (Carr, 2003). Dialogue is a central part of teaching because it helps students to clarify their ideas in relationship to scientifically accepted ideas. For conceptual development, a crucial component in teaching is formative assessment. The learning outcomes of formative assessment include ownership, social co-operation, motivation and student confidence. Formative assessment helps students in evaluating, recognizing and reacting to evaluations of their learning. Feedback that is received from students' peers enables them to reflect on their own learning (Bell & Cowie, 2001). The process of formative assessment consists of eliciting, interpreting and acting on information (Bell & Cowie, 2001). Formative assessment has many aspects which include contextual, informal, planned, unplanned, responsive, risk taking, reactive, proactive, progressive, ongoing, uncertain and interactive dimensions.

A teacher requires professional knowledge and experience in formative assessment because it is a skilled activity. In a community of learners, powerful components for motivating students are the students' self-assessments and peer-assessments (Dix, 2003).

2.3.4 Teacher-Student Interaction and Assessment

With formative assessment, the interaction between teacher and student provides the mainstay for formative decisions on student learning. For contribution to student achievement, the largest difference is often made by the quality of interaction between teacher and student (Hattie 1999; McMahon 2009). By compromising the quality of this interaction, the potential achievements of students may be diminished. This situation occurs when there is an unbalanced management focus on the curriculum instead of the needs of the students (Littlewood, 2003). Consequently, there is need to recognize the different purposes of schooling so that both formative and summative assessments are included with a balance between the two (Crooks 2004; Harlen, 2005).

2.3.5 Diagnostic or Embedded Assessment

Formative and diagnostic assessments are two terms that are often used interchangeably. Conventionally, assessment in science has focused on content. Diagnostic assessment focuses more on the conception forming process, as Treagust noted:

> Reforms in science education generally place greater emphasis on the content of curricula than on new assessment procedures. The use of two-tier diagnostic tests…can help to address many of the concerns about current assessment practices by overtly assessing the outcomes of thinking within a specified context rather than assessing knowledge of information (Treagust, 2006, p. 7).

Since the early 1970s, educators such as Tamir (1971), Doran (1972), and Linke and Venz (1978, 1979) have used multiple choice assessment items to assess student understanding in science. Part of the focus of these assessments was to diagnose student misconceptions in science, that is, students' ideas and how these ideas differ from the accepted answers (Haslam & Treagust, 1987). The purpose of the diagnostic test in science is to gather this information about the students' thought processes and conceptions about science in a short time period (Haslam & Treagust, 1987). It is believed that formative assessment can evaluate a broader base of the students' knowledge, as Treagust (2006, p. 2) recognized from Wolf, Bixby, Glenn, and Gardner's (1991) earlier work:

> In order for science teachers' pedagogy to be more effective, diagnostic formative assessment methods are needed because research suggests that current assessment procedures distort and narrow instruction, misrepresent the nature of the subject, and underscore inequities in access to education. (p. 2)

A more traditional method of understanding student ideas in science is to conduct a face-to-face student teacher interview; however, this process is too time-consuming and therefore, impractical for busy classroom teachers and also for large sample sizes. Throughout the 1980s, a number of science education researchers trialled studies on students' misconceptions on science phenomena. For example, Bell (1984) studied student understanding of plant nutrition, and Bishop, Roth, and Anderson (1985) studied the understanding of photosynthesis and respiration amongst college students.

Some authors, such as Treagust (2006), have argued that the most effective way of teaching science so that students understand the concepts is to use embedded assessment. This approach involves the science teacher using formative assessment, including diagnostic assessment, at regular intervals throughout the course to evaluate ongoing understanding and conceptual improvement in students. Diagnostic questions can be used both formatively and also summatively. Formatively, diagnostic questions are an integral part of the teaching-learning process. Summatively, the diagnostic questions are provided as an externally referenced assessment of the learners' understanding and knowledge.

One such successful approach is embedded assessment where the teachers are able to incorporate a wide variety of formative assessment procedures within their teaching (see Treagust et al. 2001). These alternative forms of assessment are different from those generally used by science teachers in that standard tests are largely paper-and-pencil collections of individual items with single correct answers presented without a surrounding context (Treagust, 2006, p. 2). Teachers can generate a diagnostic test from the database designed for the students' learning needs. Treagust stated that content definition, the identification of typical student understanding levels, and the actual development of the diagnostic test (Treagust, 2006, p. 3).

In brief, there are three major aspects in developing these items: (a) the content is defined by the identification of propositional content knowledge statements of the topic to be taught and the development of a concept map that accommodates the propositional statements; (b) information about students' conceptions is obtained from the extant research literature, where available, and where not available by having students provide free response explanations to their answers and conducting unstructured interviews with students who have previously been taught the content/concepts; and (c) the development of the two-tier multiple choice diagnostic test items.

After students have finished the diagnostic test, teachers can then generate a rich data report showing individual learning achievement, group learning achievement, as well as the individual's and groups' position progress in relation to the total number of learning steps and overall curriculum. The Ministry of Education in New Zealand has launched nationwide initiatives using diagnostic testing/reporting to benchmark performance norms for students (New Zealand Ministry of Education, 2010).

2.3.6 Assessment of Alternative Conceptions

The principles of constructivism have paved the way for new perspectives or even targets of assessment. Instead of the focus being on a yes or no question of whether the students know the correct answer or not, the objective for constructivists is characterise the exact understanding of the student, as much as it is possible, with less emphasis its accuracy or inaccuracy. As Tsai and Chou (2002, p 157) explained, based on earlier work by Driver and Easley (1978) and Wandersee, Mintzes, and Novak (1994):

> During the last 25 years, many science educators have believed that students' knowledge in domain-specific areas plays a more important role than their general cognitive ability or underlying logical structures on conceptual learning of science (Drivwer & Easlet, 1978). Consequently, science education researchers have widely surveyed students' knowledge in various domains, known as students' 'misconceptions' or 'alternative conceptions.' (see Wandersee et al., 1994).

This research trend facilitates the practice of constructivism in the field of science since it is important to know what prior knowledge students bring to a learning environment in order to help them construct new knowledge.

Ascertaining students' alternative science conceptions has become a goal of many progressive scholars and now there is even a large number of online diagnostic instruments which have been developed (Treagust, 2006). Of these online diagnostic instruments, most were developed for specific areas of science and only a small number of these has been developed using a two-tier multi-choice format. Using random sampling procedures, conceptions of students were identified using two-tier diagnostic tests in the Taiwan National Science Concepts Learning Study (Chui, Guo, & Treagust, 2007). A networked test system using three two-tier items was developed by Tsai and Chou (2002). A 47-item Science Belief Test, developed by Larrabee, Stein, and Barman (2006), was a computer-based two-tier instrument with which misconceptions in science of students were identified by examining the students' true-or-false responses in the second tier to support their responses in the first tier. This instrument is similar to the online diagnostic instruments because both test a variety of science concepts over a wide range of scientific disciplines.

2.4 Two-Tier Tests for Educational Practice and Research

2.4.1 Significance of Two-Tier Tests

Two-tiered multiple choice diagnostic instrument tests the student's answer to a question as well as the student's justification for that answer (Treagust, 1988, 1995). In other words, the first tier of the instrument involves a multiple choice question based on the target content with three or four alternatives. The alternatives are based on authentic and rational responses that students historically make regarding that topic. Therefore, the alternatives for the first tier of the instrument serve as distracters (Lin, 2004). The second tier of the diagnostic instrument contains multiple choice options for each of the options in the first tier. Therefore, if there are three options in the first tier, there will be a total of nine options in the second tier (i.e., three times three); however, the respondents only are asked to answer the second tier items which correlates with their choice for the first tier items. The steps in the development of two-tier tests by Treagust (1988, 1995) are shown in the schematic diagram in Figure 2.1 (Treagust, 1988, 1995; Treagust & Chandrasegaran, 2007).

The two-tier approach to assessing student understanding has a number of advantages for the researcher. Primarily, the tool is very time efficient. Mann and Treagust (1998) commented that it is a format which overcomes the need for lengthy student answers as were required previously to justify their responses. Lai (2007) asserted that the strength of the two-tier approach is that as there are so many abstract concepts in science, it is important that science teachers have an awareness of their students' conceptions and misconceptions. Lin (2004) provided a good example of a two tiered diagnostic instrument in the study about student misconceptions of plant growth.

Single level multi-choice diagnostic instruments only explore students' understanding at a superficial level. Deeper examination can be made by the use of questions at two different levels (Millar & Hames, 2001). For students working at specific levels in particular science topics, instruments have been developed in similar two-tier diagnostic tests. The different topics are animal classification, breathing, osmosis and diffusion, the formation of an image through a plane mirror, characteristics of matter, flowering plant growth and development, astronomy, and plant and human circulation (Treagust & Mann 2000). In particular scientific topics, two-tier diagnostic instruments were developed in order to ascertain alternative conceptions. For students at a range of levels, a broad-based set of two-tier items for chemistry were developed by Chiu (2005), which covers a wider range of alternative conceptions in chemistry. Chandrasegaran, Treagust, and Mocerino (2008) used a two-tier instrument to evaluate a teaching intervention to enhance students' ability to use various levels of representation to describe and explain chemical reactions.

Examples of several two-tier tests that have been developed in the past are summarised in Table 2.1 below.

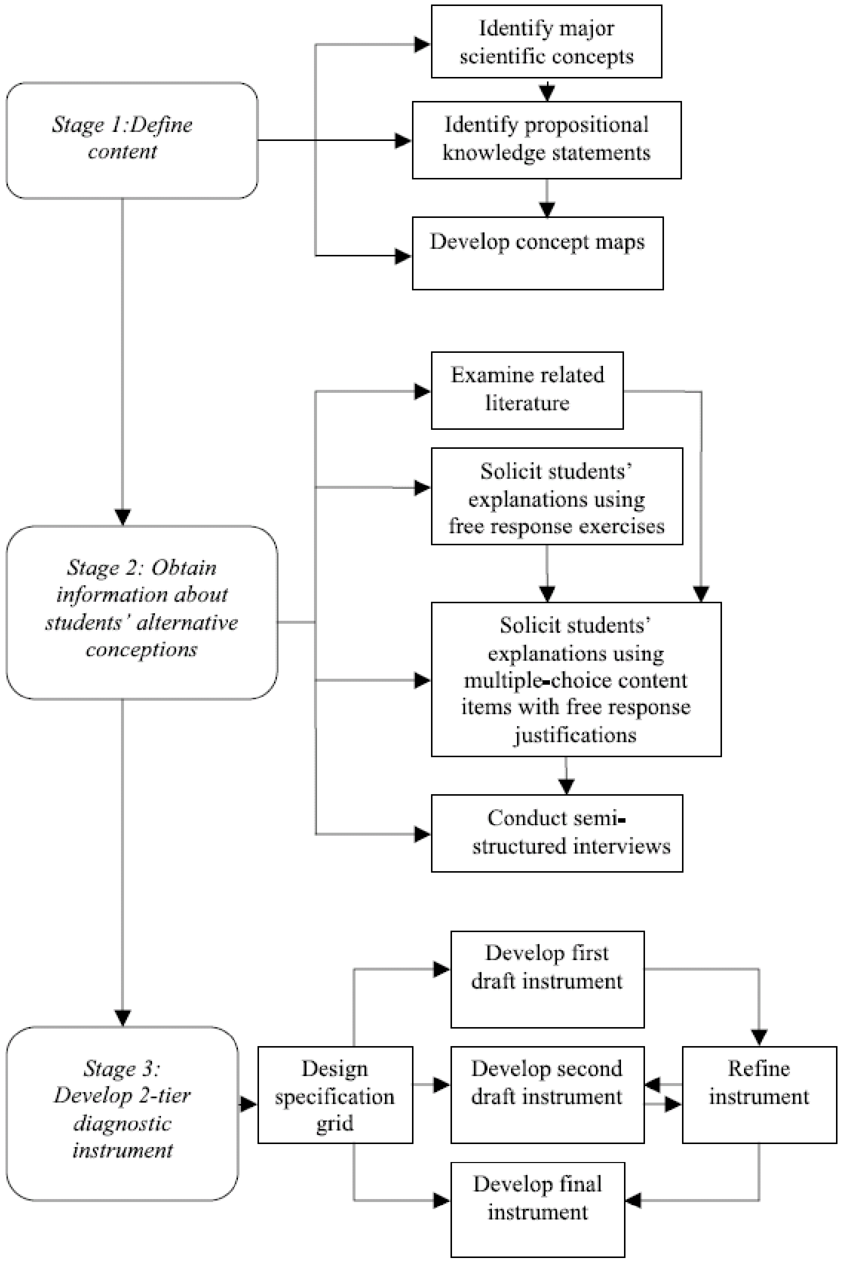


Figure 2.1 Stages in the development of two-tier multiple choice diagnostic instruments based on the methodology proposed by (From Treagust, 1988, 1995; Treagust & Chandrasegaran, 2007)

Table 2.1

Summary of the Development of Diagnostic Instruments

Topic/Concept	Author(s)
Photosynthesis and respiration	Haslam and Treagust (1987)
Diffusion and osmosis	Odom and Barrow (1995)
Breathing and respiration	Mann and Treagust (1998)
Internal transport in plants and the human circulatory system	Wang (2004)
Flowering plant growth and development	Lin (2004)
Covalent bonding and structure	Peterson, Treagust, and Garnett (1989)
Chemical bonding	Tan and Treagust (1999)
Qualitative analysis	Tan, Treagust, Goh, and Chia (2002)
Chemical equilibrium	Tyson, Treagust, and Bucat (1999)
Multiple representation in chemical reactions	Chandrasegaran, Treagust, and Mocerino (2005)
Ionisation energies of elements	Tan, Taber, Goh, and Chia (2005)
Acids and bases	Chiu (2001, 2002)
States of matter	Chiu, Chiu, and Ho (2002)
Light and its properties	Fetherstonhaugh and Treagust (1992)
Formation of images by a plane mirror	Chen, Lin, and Lin (2002
Forces	Halloun and Hestenes (1985) Hestenes Wells, and Schwackhame(1992)
Electromagnetism	Paulus and Treagust (1991)
Electrical circuits	Millar and Hames (2001)
Force, heat , light and electricity	Franklin (1992)
Scientific knowledge	Chiu, Guo and Treagust (2007)

The use of two-tier diagnostic tests can help to focus on concerns about existing assessment practices. This is achieved not by assessing knowledge of information but by openly judging the outcomes of thinking about scientific concepts in a specific context. Using their test science teachers can achieve better understanding about the nature of students' understanding and the existence of any alternative conceptions or misconceptions within a particular topic being studied. This can be achieved by using these diagnostic instruments at the beginning or on completion of a specified topic. After students' alternative conceptions are identified, science teaching can be modified by incorporating conceptual change teaching approaches (Duit & Confrey, 1996). The way a student thinks can be challenged by developing and/or using alternative methods of teaching that exclusively address students' non-scientifically acceptable conceptions. For example, some students have problems in understanding the ideas of reduction and oxidation (Tan, Treagust, Goh, & Chia, 2002) because at least three models of redox (reduction and oxidation) reactions are commonly encountered in chemistry courses (de Jong & Treagust, 2002). Therefore teachers need to pay close attention to the ways in which they give instruction to clarify the models so that students will feel confident to use them in order to decide whether a chemical reaction is a redox reaction. The same is true for many science topics. In Tan, Treagust, Goh, and Chia's (2002) study, the students' understanding of other topics and practical chemistry were assessed with the diagnostic test which the team titled the Qualitative Analysis Diagnostic Instrument (QADI).

Many experienced teachers certainly recognize students' conceptions identified by two-tier diagnostic instruments. However, less experienced teachers only appreciate these conceptions after they have received the instruction. In the case of the less experienced teachers, it is not possible to consider students' conceptions and to integrate these in the teaching process. Research evidence also suggests, however, that even experienced teachers are often found not to appreciate some of the problems encountered by students in learning multifaceted science concepts (Widodo & Duit, 2002). There are two reasons for this. First, usual approaches to teaching do not sufficiently look for reasons for answers. Second, the common assessment procedures do not stipulate detailed explanations of concepts.

The significance of the national Taiwanese data using these diagnostic tests can be attributed to the fact that they can be generalised across the nation. As a result, there is much less likelihood for teachers to believe that different conceptions identified in students' responses in another teacher's class or in another school will be rejected and not be considered as being relevant to their classes. Reported data from a study of students in Taiwan is important because it provides a national overview of students in Taiwan and their understanding of a range of science subjects and the underlying concepts. The Taiwanese data can be used in a similar way as those of TIMSS and PISA, although it uses a different assessment system, to identify directions for future development in science education. In many countries there is much concern about the low participation rate of students taking science, especially in higher levels of secondary school education (OECD Global Science Forum, 2006). Therefore this issue is certainly not inconsequential. As discussed in Chapter One, Australian enrolments, particularly, are on the decline and there are also notable enrolment declines in countries such as Great Britain and France (Nature, 2002).

Improvements in the foundations of science education in primary and secondary schools are necessary. In particular, the success and the continuation of science programs at university are dependent on these developments. The science education community faces a major challenge which is to address this decline in enrolments in science subjects. Science needs to be presented in such a way that it is perceived as understandable and interesting in order to encourage more students to study science subjects. Formative assessment can play a key role. For example, students can start to question and comprehend the underlying science concepts based on their responses to the questions, by using multiple choice diagnostic items. Students are encouraged to think about the concepts through formative assessment incorporated into teaching. They are also taught and supported to consider alternative explanations rather than memorise basic facts for a test or examination that are later forgotten.

2.4.2 Formative Diagnostic Assessment

There is evidence from a range of studies that formative assessment using tests can increase students' understanding of concepts. There is, however, an extensive body of research that shows that teachers' knowledge and awareness of the findings of science education research in general is still very limited (Gilbert, Justi, van Driel, de Jong, & Treagust, 2004). Teachers who are likely to be early advocates of applying the results of such research are often those who find the time to be involved in research studies.

Other teachers simply do not have the time or means of accessing research journals for scientific education, and even when these become available, there is a significant time lapse before teachers become aware of the research findings. Therefore, there is a need for initiatives that will make speedy communication of scientific education research findings to the classroom more possible. An example of this is the Evidence-based Practice in Science Education project organized by Millar (2003) in the United Kingdom. This has resulted in the development of a number of formative diagnostic instruments that consist of various kinds of items including two-tier multiple choice items as well as others that require students to give reasons for their answers to particular items. These instruments are available on the Internet.

In general, teachers may have a better understanding of students' learning difficulties if information about the findings of the range of alternative conceptions related to particular concepts were available on CD-ROMs or the Internet. The availability of this information on the internet and so forth could potentially be of invaluable support to teachers for planning as well as implementing classroom instruction.

The data from the Taiwanese National Science Concept Learning Study at a research level can be seen to be the beginning of a concentrated examination of the teaching approaches and curriculum using the model of educational reconstruction (Kattmann, Duit, Gropengießer, & Komorek, 1995). This consists of an analysis of experimental investigations of student's understanding of science content, content structure and the construction of instructional modules. When taken to the classroom level, the teacher can obtain feedback on the type of follow-up remediation that needs to be undertaken by including a relevant multiple choice diagnostic instrument in assessing students' understanding. However the successful initiatives such as the model discussed above will depend on strong links between classroom teachers and academic researchers.

2.5 Diffusion, Osmosis and the Particulate Nature of Matter

2.5.1 Significance of the Particulate Nature of Matter

The particulate nature of matter is one of the central, underpinning concepts of both chemistry and physics (El-Sayed, 1987; Singer, Wu, & Tal, 2003; Yezierski & Birk, 2006; Yeany & Miller, 1983). This theory holds that matter is made up of small particles, each of which is too small to be seen, and that these particles constitute all matter as we know it. Part of the theory also holds that these particles are all in constant motion. In most countries the theory of the particulate nature of matter is embedded in the middle school curriculum, that is, for adolescent children aged between 13 and 15 years of age depending on the students' aptitude and class level.

However, repeatedly, in the body of literature the particulate nature of matter is cited as one of the most problematic concepts for both students and science teachers alike to grasp (Singer et al. 2003). One problem is confusion between the macroscopic and microscopic behaviours, as Othman et al. (2008) commented:

> …students regard particles as small pieces of an object with all its properties, because they have yet to make the distinction between matter (substance) and objects. In addition, students believe that there is no empty space between particles, that there is 'stuff' between molecules and that molecules are in substances rather than a substance is composed of molecules. (p. 1532)

Another one of the problem areas for students regarding the particulate nature of matter relates to changes in state. For example, students appear to struggle with the role of particles and changes in their behaviour as a substance that moves from gas to liquid and to solid. Instead of a change in the movement of the particles, the students perceive more profound changes occurring. Othman et al. (2008) also found this and commented:

> The bubbles [of boiling water] were believed to consist of heat, air, oxygen, or hydrogen, and steam; air being the most commonly held view…there is no sense that the water can be in the air as a vapour. (p. 1532)

In a study on 20 primary school students, Valanides (2000) reported that the student teachers "had difficulties to relate the observable macroscopic changes to the invisible molecular changes" (p.249). Yezierski and Birk (2006) studied 719 high school students and found that visualisation difficulties were present in the majority of students when it came to understanding the particulate nature of matter at the microscopic level; and they concluded that computer animation could help students visualise the microscopic concepts. The research conducted, thus far, suggests that students hold a range of alternative conceptions about atoms and the molecules (Singer et al., 2003). Such alternative conceptions include seeing matter as cloud-like, or seeing matter as something which expands or contracts with the individual particles expanding and contracting (Singer et al. 2003). Othman et al. (2008) reported on studies that find students consider matter to be small portions of a continuous substance; and they also found in their studies on the particulate nature of matter that most students believe that there is no empty space between molecules.

The literature reports that the difficulty students have with understanding the concepts of the particulate nature of matter stem from the troubles teachers themselves have with the concepts (Yeany & Miller, 1983; Singer et al., 2003). As Zuckerman (1993) argued, "they may not have had the opportunity to construct this knowledge because their teachers were unaware of some subtle pieces" (p. 5). There is a problem in that not all teachers understand the content they are teaching (Haslam & Treagust, 1987).

2.5.2 Diffusion and Osmosis

The particulate nature of matter theory also has implications for the understanding of biology as students are far better equipped to understand the processes of osmosis and diffusion, once the principles of the particulate nature of matter are understood. Diffusion and osmosis refer to the movement of particles in and out of cells and tissues throughout the body. Both processes are vital for ongoing good health and survival of the body. Diffusion is a broader term which refers to the movement of particles from areas of high concentration to areas of lower concentration. However, diffusion has underlying processes which are random and spontaneous. Many students, and teachers, misunderstand this aspect of diffusion particularly when it is discussed in relation to the body, as Garvin-Doxas and Klymkowsky (2008) commented:

> The last response [diffusion occurs because of a random event due to thermal motion] was one of the very few responses that acknowledged the role of random molecular motion. The majority (95% of approximately 100) of responses are typified by the other examples, where diffusion is viewed as directional movement that takes place *only* when some kind of gradient exists. There is no apparent appreciation displayed that random processes can give rise to emergent behavior, such as net directional movement of molecules. (p.231)

In contrast, osmosis refers to the specific movement of water particles in and out of cells depending on the concentration of salts in the cells. Diffusion and osmosis are taught as part of most high school science curricula.

Some spatial aspects of the theory have been found to be troublesome for students. The body of literature on the teaching and learning of these biological concepts has often mentioned the difficulties that students have. Abdo and Taber (2009) commented that if students miss this vital stepping stone, they later struggle with the whole field related to molecular biology concepts. Diffusion and osmosis lie at the core of the fundamental knowledge of life sciences (Yager, Tamir, & Kellerman, 1994). Johnstone and Mahmoud (cited by Odom & Kelly, 2000) found in their study that high school biology students perceived diffusion and osmosis to be among the most difficult topics in biology. Abdullah el Zahra (1992) found the same in studies in Iraq. Five areas of alternative conceptions were found relating to the students' understanding of the particulate nature of matter. These were concentration, toxicity, life forces, diffusion and the processes of the actions (Odom & Kelly, 2000). Odom created and tested the Diffusion and Osmosis Diagnostic Test in 1995. Diffusion is another concept which is problematic for students of science. Diffusion is the primary method of short distance in cells and the greater cellular systems (Odom & Kelly, 2000) Osmosis, a biological phenomenon, is a concept based on diffusion of which students need to have an understanding in order understand water intake, water balance in plants and animals, as well as other more physically based concepts such as turgor pressures and transport in living organisms (Odom & Kelly, 2000). The issue with misunderstanding diffusion and osmosis, is that when students miss the foundations, understanding more complicated biological processes becomes more difficult (Duit & Treagust, 2003; Treagust, 1998).

2.5.3 Teaching Challenges

The teaching of these concepts has been challenging up to now (Odom & Kelly, 2000). Research shows that, following instruction, many students only have a limited understanding of such science concepts (Duit & Treagust, 2003). If not challenged, the students' misunderstandings, that is, the alternative conceptions, become embedded into their cognition. After testing the Diffusion and Osmosis Diagnostic Test with 355 high school and university biology students, Odom and Kelly (2000) found that there was a noticeable difference in the results between biology majors and nonbiology majors. What this suggests is that the concepts of diffusion and osmosis are better understood by biology majors and not well grasped by students majoring in other subjects.

2.6 Alternative Conceptions

2.6.1 Evolution of Alternative Conceptions and their Significance

For some time now, academics have been investigating in depth the processes of question answering and understanding (Treagust et al., 2009). What is being found is that, for each question, there are a number of common conceptions or misconceptions that students hold. Seeing through their own eyes, students construct coherent and sensible understandings of concepts and phenomena (Nakhleh, 1992). Peterson et al. (1989) used the measure that when more than 10% of the student body holds an alternative conception, that is, a conception not conforming to the accepted thinking of the scientific community (Johnstone, 1997), the conception will be considered to be a valid alternative conception. Students' cognitive structures are influenced by these conceptions if they are not challenged, and therefore these conceptions may interfere with students' subsequent learning. This results in inappropriate understanding of subsequent concepts with students having difficulty in integrating new information into their cognitive structures

Since the 1970s, several terms have been coined referring to the same topic matter, including alternative frameworks (Driver & Easley, 1978; Driver & Erickson, 1983), children's science (Gilbert, Osborne & Fensham, 1982), misconceptions (Cho, Kahle & Nordland, 1985; Griffiths & Grant, 1985), preconceptions (Anderson & Smith, 1983; Hashweh, 1988) and alternative conceptions (Gilbert & Swift, 1985). As an acknowledgement of students' individually built knowledge, the term *alternative conception* is now used by educationists. Authors have identified alternative conceptions in learners' explanations of many scientific concepts and methods.

The study of these alternative conceptions is valuable for many reasons. Educators are able to see how students construct their answer and are able to consider and reconsider how best to teach content so that students attain the correct scientifically accepted answer. In a study on students' understanding of kinetic particle theory concepts involving 148 high school students in Brunei, Australia, and Hong Kong, Treagust et al. (2009) reported on the implications of their investigation: "The information obtained by teachers as a result of using these items will facilitate appropriate measures to be taken by them during classroom instruction to address any alternative conceptions that may be held by the students" (p.142). Often, personally constructed representations of students are not equivalent to the thinking that is scientifically accepted because abstract concepts are often unfamiliar to the students.

There have been a number of studies which have pointed to the phenomenon of students knowing answers but are not able to provide justifications for their answers (Treagust et al., 2009). In a study of the student's responses to an examination of conceptual knowledge (Bodner, 1992), graduate students at Purdue University responded in a way that indicated that the students possessed knowledge without an understanding. Depending on the contexts in which the concepts were introduced, the student's understandings were constructed from these concepts they learn, for example, in the textbooks, laboratory work and lectures. Therefore, students were not able to apply the knowledge of these subjects to their own understanding of the world, outside the classroom. A significant number of these undergraduate students in Bodner's study maintained these alternative conceptions even after an extensive exposure to chemistry in the laboratory and in lectures. Teachers need to know about the alternative conceptions of the students because their alternative conceptions are naturally resistant to instruction (Bodner, 1992). Students will persist in constructing their own understanding of concepts if no action is taken at an early stage of schooling. It is important for academics and classroom teachers to be aware of, and understand, these alternative conceptions to bring about early intervention in students' learning.

However, research suggests that the term "alternative conceptions" is not a term that is well received by classroom teachers. This may be due to the fact that classroom teachers expect students to understand explanations. Therefore, a term like "students' conceptions" may be more acceptable to classroom teachers (Treagust, 1995).

2.6.2 Importance of Alternative Conceptions in the Study of Science

From primary school through to the undergraduate level, many students find chemistry difficult to study, resulting in students failing to master the subject (Nakhleh, 1992). A number of concepts in chemistry can be easily misconstrued. Yarroch (1985) and Andersson (1986) both found that student misconceptions regarding the arrangement of atoms in matter was an example that posed difficulty to students. This is a weakness, and as a result of the misunderstanding of concepts from the commencement of their studies, students are not able to understand advanced concepts which are based on the fundamental concepts. As an example, a balanced chemical equation may not be understood by students as representing the rearrangement of atoms (Yarroch, 1985). Students also find it difficult to distinguish between physical and chemical changes depending on whether or not rearrangement of atoms has occurred to produce new substances (Andersson, 1986).

Rather than perceiving chemical equilibrium as a dynamic state at equilibrium, students perceive a static state (De Vos & Verdonk, 1986). In a study that discussed the difficulties experienced by chemistry students, particularly undergraduate students, the application of principles and chemical equilibrium in relation to reaction rates were prominent; and consequently, teaching modules were developed for teachers in teaching chemistry to tertiary students and senior high school students (Power & Banerjee, 1991). Some of the many findings that are documented in the literature relate to oxidation and reduction equations, electric circuits and also electrolytic and electrochemical cells (Pamela J. Garnett & Treagust, 1992).

As through their own eyes, students hence construct a coherent and sensible understanding of the concepts and phenomena (Nakhleh, 1992). Students' inappropriate understandings will be integrated into their cognitive structures and if not challenged, will interfere with their subsequent learning. As a result, the student will find it difficult to integrate any new information that is processed within their cognitive structures.

2.7 Attitudes Towards Science

2.7.1 Introduction

As we move through the 21st century, science and technology are having significant impact on Saudi society. Therefore, it is vital that future generations of Saudi students acquire positive attitudes and perceptions towards science in order to optimize the use of science in the region (Bakar, Bal, & Alcay, 2006). Lack of interest in science is a phenomenon which is causing great apprehension in a number of settings. Hassan (2008) argued:

> The number of students taking science in Year 11 and 12 in Australia has been falling steadily since 1976, and the proportion doing physics has almost halved. Other research has shown that the decline in science enrolments is related to many interrelated factors such as the students' academic abilities, teaching methods, the absence of motivation to study science and lack of interest in science subjects. There is a growing concern that this reduction in enrolments in science and technology subjects is threatening the success of the country's innovative economy. (p. 192)

For future science teachers, shaping the understanding and attitudes of generations of students, as wells as a positive stance on the value of science are essential (Yager, 1994). Students' experiences, and the overall view of science education that they receive, affect their interests and motivation towards learning and a positive encounter with science at this level could lead to students undertaking fruitful careers in science-related industries.

2.7.2 Research into Attitudes Towards Science

In 1980, Moore and Sutman developed the Scientific Attitudes Inventory (SAI). This instrument is commonly cited (Hassan, 2008). A revised form was published in 1997, by the pair and was titled SAI-II. The revised version, SAI-II, attempted to measure both attitudes which were considered intellectual and attitudes which were considered emotional (Hassan, 2008). The collective attitude of the community towards science has been investigated throughout time. In one study of 2000 British respondents, Evans and Durant (1995) explored common public opinion on a range of topics in science and science education. They found that the greater public was largely supportive of science. With more than 80% of their sample supporting increased funding for scientific research. They also found that people believed that research into cancer was the most justified area for scientific research funding followed by studies into physics and nuclear power.

The relationship between students' attitudes and their learning outcomes in science is also an area of attitudes towards science which has been investigated for some time (Masu, 1989; Coulson, 1992). The phrase or concept, *attitudes towards science*, refers to "either a positive or negative general feeling about science" according to Masu (1989, p. 23). Although people at large do appreciate the value of science in our society, Evans and Durant (1995) concluded in their study that "there is no easily defined general attitude towards science" (1995, p. 70). What the researchers did find out, however, was that the more knowledge people had about science, the more they trusted science.

2.7.3 Factors Affecting Attitudes to Science

A number of factors influence attitudes towards science both among teachers and students. Fraser (1988) reminded teachers to be mindful of factors that may contribute to creating a more positive learning environment that fosters positive attitudes towards science. Saudi (1988) summarised the findings of various researchers regarding the attitudes of pre-service teachers. University students who are intending to become teachers have more positive attitudes towards science than their colleagues not intending to be science teachers. Gawahirgi (1991) suggested that the influence of parents and other relatives was an important factor in the development of children's attitudes to science. Another factor is the influence of others during their study periods. Gawahirgi further posited that communication about scientific projects and achievements through the media also influences attitudes.

According to Hattab (2002), while students acquire scientific knowledge through education, attitude is more important than education in the acquisition of knowledge. The argument is that knowledge may change or be lost, but attitude is always present. Germann (1988) suggested that students who are positive about science have a greater willingness to study more diverse science topics, and achieve better results. On the other hand, Salta and Tzougraki (2004) demonstrated a negative relationship between students' attitudes and their academic results in chemistry.

Osborne, Simon, and Collins (2003) suggested that important factors influencing students' attitudes are the teachers, their teaching strategies and their preparation to implement strategies in practice. Jarvis and Pell (2005) demonstrated, in a study of 300 students aged ten to eleven in Britain, that when students' understanding of the value and importance of science in the community was raised, they showed greater willingness to study science.

El 'Abdil Kareem (1999) concluded from a study of first year secondary chemistry Saudi students that electronic teaching methods were not a factor influencing their attitudes. El Hariki and Moussa (1995) reported on the attitudes of male and female, intermediate and secondary students, in Saudi Arabia and their achievements in science subjects. Geographic location is also relevant. In Saudi Arabia, a number of experts have mentioned that there is a marked difference between the attitudes of students towards science in cities, and that of their peers in rural settings. According to Shatat (1989), Saudi high school students' attitudes to science became more positive at increasing levels of education. Also high achieving students displayed more positive attitudes than their lower achieving colleagues.

2.7.4 Negative Views Towards Science

Most experts find that determining a defined general attitude towards science is difficult (Evans & Durant, 1995). While studies suggest that, on the whole, groups are not strongly opposed to science, the outcomes infer that the less knowledge people have of science, the more likely these groups are to hold negative views towards science (Evans & Durant, 1995).

In addition, in 2003, Osborne et al.'s (2003) review of the literature on attitudes towards science in the United Kingdom concluded that the majority of students did not like the subject; "far too many pupils are alienated by a discipline [science] that has increasing significance in contemporary life" (p. 1073). In an earlier study, Long, Okey, and Yeany (1981) conducted a study with 93 upper secondary students in an attempt to gather data on high school students' attitudes towards biology. Two trends were found. First, students' attitudes towards biology were more favourable as the students spent more time in the biology class. Second, the more assessment items were presented to the students, the more the students were interested in the subject. These results demonstrated the influence of external motivators on the students. Other researchers, such as Gibson and Chase (2001), have found that the principal factor influencing high school students' attitudes towards science is the method of teaching used by the teacher. Selim and Shrigley (as cited in Gibson & Chase,2001) found that the discovery approach — an inductive method of teaching whereby students learn through experience — led to positive attitudes towards the discipline. On the contrary, more traditional approaches such as teacher-led lecturing resulted in negative views of science among students.

2.7.5 Rationale for Gaining an Awareness of Attitudes Towards Science

There seems to be two main reasons, in terms of teaching and learning, as to why understanding current attitudes towards science is useful. First, students have a need to know and a need to succeed in life, and a positive attitude towards science can be a vital component of their progress (Masu, 1989). Some refer to this as a natural instinct to grow and learn (Masu, 1989). Through promoting positive views towards science, growth and development can be encouraged. Second, students' attitudes towards science affect their future work choices. In many economies throughout the world, there is demand for highly skilled employees well versed in science disciplines such as biology, chemistry and physics. Teachers have a role in encouraging students to pursue careers in these areas. In order to do this, the teachers need to acknowledge their own predisposition towards the discipline and its effect on the tendencies and opinions of their students. Naturally, the teachers' views about their own discipline are consciously (or unconsciously) passed on to the students. To this effect, Bhushan (as cited in Masu, 1989) asserted that teachers' attitudes towards science are likely to affect their students' attitudes. Other researchers, such as Coulson (1992), suggested that the early philosophical models based on Piaget's developmental processes have relevance regarding students' attitudes towards science.

2.7.6 Student Achievement and Attitudes Towards Science

Students' first impressions of science and the way that lessons in science are conducted have a direct relationship with the students' achievements in the subject.

A number of studies have found that when other variables are controlled a clear affiliation between attitudes towards science and achievement in science can be seen (Fraser, 1998). Philosophers such as Armstrong and Kahl (1979) have highlighted the significance of developing a positive attitude towards science, and how the experiences school children first have with the area of study can lead to beliefs which are held for a lifetime.

One important instrument in the study of students' attitudes has been the TOSRA (Fraser, 1981). The format of TOSRA requires students to respond to a number of statements in terms of the extent to which they agree or disagree based on a five-point Likert-type scale which ranges from Strongly Agree, Agree, Not sure, Disagree, to Strongly Disagree. For data analysis purposes, the points of the scale are all given a numerical values, that is, 5 = Strongly Agree, and 1 = Strongly Disagree for positively-worded statements. The scores are reversed for negatively-worded statements. The items are distributed in seven scales and the means and standard deviations of the combined responses to the items in the seven scales of the TOSRA can readily be determined (Fraser, 1981). Hassan (2008) gives the following account of TOSRA in his study of Australian university students.

> ... The Test of Science-Related Attitudes (TOSRA) (Fraser, 1981), which attempts to measure seven science-related attitude scales. TOSRA has been tested and was shown to be 'highly' reliable (Khalili, 1987) with sound theoretical basis and an impressive empirical validation... (p. 133)

The TOSRA was first developed to assess the seven aspects of students' attitudes towards science. Designed in 1977, the instrument has undergone a number of cross-validation studies over the past thirty years including use in post-secondary education. Lucas and Tulip (1980) tested TOSRA on 740 students in four separate high schools in Brisbane, Australia. Schibeci and McGaw (1980) ran the test with a sample of 1041 lower school students (Years 8 to 10) in eleven schools in Perth, Australia. In the United States, in Philadelphia, 546 Year 9 students from a Catholic school were involved in a TOSRA research project (Fraser & Butts, 1982) that also included a study in Sydney, Australia, with a larger sample of 712 lower school students from 23 different classes. From all of the above administrations of the instrument the internal consistency was found to be high with satisfactory discriminant validity reported. These results were congruent with Fraser's (1981) early tests of reliability of TOSRA. Fraser tested the internal consistency reliability, namely, whether there was a clear fit between the items on a TOSRA scale and the attitude towards science that it was allegedly measuring, using the Cronbach alpha coefficient (Cronbach, 1951). The alpha reliability coefficient values ranged between 0.64 to 0.93 with a very slight variation across the seven scales, which meant that the mean value of the alpha reliability coefficient ranged between 0.80 and 0.84. On interpreting this, it can be said that this means the mean reliability coefficient is high given that the scales only had ten items. Furthermore, it can be added that the internal consistency reliability of TOSRA is appropriately high at each scale. The reliability of TOSRA has, therefore, been thoroughly attested to by these trials and through research conducted since. The empirical validity of TOSRA suggests that there are trends which can be observed in terms of student attitudes towards science.

This field of research has led a number of educational bodies to respond by embedding notions of positive student attitudes towards science in their statements of goals and visions. The National Science Education Standards (1996) in the United States state that one of its core goals for school-based science is to encourage situations whereby students are able to experience the excitement and richness of the natural world through knowing and understanding the phenomenal processes which are involved. The advantage of this, according to the literature, is two-fold. First, students have higher likelihoods of developing positive attitudes towards the discipline through this exposure. Second, and more importantly, students are encouraged to maintain these positive views. The importance of teachers developing positive attitudes towards science has long been highlighted in the literature about what makes a good teacher. For example, Rosenthal (1968) found that when instructors held negative attitudes towards science, this negativity was transparent in their teaching, and hence influenced their students' attitudes towards science.

2.7.7 Attitudes Towards Science in the Gulf Region

Attitudes towards science in the Gulf region, and its greater surroundings, appear to be indicative of a need for improvement. There have been a number of reports about flaws in the current Saudi Arabian science curriculum (Al-hurr & Ar-rumi 2002; Radwan, 1991). Al-hurr and Ar-rumi (2002) reported that there is evidence of defeatism in education in many of the Gulf Countries. Motaweaa (1995) in a study with biology teachers in Egypt found that there were large discrepancies between the intended and the actual knowledge. The lack of effectiveness, specifically in Saudi Arabian science instruction, is of concern to authorities (Radwan, 1991). This lack of efficacy in Saudi Arabian science instruction has a direct negative impact on the students' understanding and attitudes towards science-related subjects.

2.7.8 Attitude Towards Science in this Study

This study questioned about the current status of Saudi Arabian students' attitudes towards science and speculates the reasons why these attitudes may have changed in recent years. From the seven scales of the original TOSRA, this study focused on results from the three most reliable scales, namely, "Attitude to Scientific Inquiry," "Adoption of Scientific Attitudes" and "Enjoyment of Science Lessons." The study attempted to understand the determining factors of students' attitudes and highlights the causes of their negative attitudes. The rationale behind this study was to identify teaching and learning practices which result in negative outcomes in terms of students attitudes towards science. More importantly, the goal of this inquiry was to identify and recommend means to encourage more positive views towards science education and commercial science for Saudi Arabian teachers, students and teachers-in-training.

2.8 Summary

This chapter has:

- Described some of the history and importance of theories of learning, including knowledge acquisition, and discussed the influence of social and cultural factors on the development of a student's position towards science shown that different stages of cognitive development exist and learning is more effective when students are active participants in the learning process.
- Presented evidence that students develop their unique conceptions of scientific phenomena depending on their prior experiences with this content.
- Outlined the characteristics of the two main types of assessment formative assessment, evaluation during a certain learning program, and summative

assessment, evaluation at the end of a certain course; and discussed the various formative and summative assessment instruments that have been developed, highlighting the position of embedded assessment involving formative assessment, throughout the learning period.

- Introduced current positions of diagnostic tests, characterizing assessment instruments, most notably two-tier diagnostic tests, as being vital for teachers in terms of understanding the alternative conceptions of their students thereby allowing the teachers to modify teaching methods accordingly.
- Illustrated how the use of diagnostic tests can have an almost immediate impact on student learning if combined effectively with formative assessment
- Highlighted the role of the particulate nature of matter as a fundamental scientific concept due to its implications for chemistry, physics and biology and reviewed studies which have found that students have difficulties with the concept.
- Discussed diffusion and osmosis as fundamental concepts with significance in the life sciences but many biology students consider these the most difficult concepts to understand.
- Defined the term "alternative conceptions" as the students' conceptions, which are based on the students' own understanding and experience, and are outside of conventional accepted scientific thinking.
- Illustrated how an appreciation of the derivation of various alternative conceptions is important for educators as it enables them to adjust teaching so that students are left with the accepted conceptions of science.
- Commented on the Saudi educational setting with regards to an increasing need for the science and technology skills and knowledge.
- Asserted that a positive attitude towards science is vital to attain maximum student achievement. This position is based on a number of research articles about students' attitudes towards science recognising that educators must understand their students' attitudes towards science.
- Demonstrated that there are a number of factors that educators must be aware of and that are reported to better influence students' attitudes towards science.

- Argued that teachers require assistance to better understand their students' attitudes towards science and presented TOSRA as a leading diagnostic instrument for the purposes of gathering data, which can be used to draw out the main themes in terms of student attitudes.
- Concluded by stating that there were a number concerns with students' attitudes towards science in the Gulf region, and for this reason, the use of TOSRA in this study is required.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

The purpose of this study was to investigate Saudi Arabian pre-service science teachers' understanding of diffusion, osmosis and the particulate nature of matter and their attitudes towards science. This chapter describes and explains the methodology and research methods used by the researcher in answering the five research questions stated in Chapter 1. This chapter is divided into nine sections each describing a different component of the methodology used in this research. Section 3.2, following the Introduction, describes the participating pre-service teachers involved in the study. The research setting is outlined in Section 3.3. The results of the pilot trial used to validate the research instruments are discussed in Section 3.4. The research paradigm is discussed in Section 3.5 highlighting the use of triangulation in a mixed methods design. The steps of the data collection processes are presented in Section 3.6. The analysis and interpretation of data gathered are presented in Section 3.7. An important feature of the research is the assurance of data quality; to meet this goal, criteria used to assess the study's quality are presented in Section 3.8 whereas associated ethical issues pertaining to the study are explained in Section 3.9. A chapter summary concludes this part of the thesis (Section 3.10).

3.2 Participants

The study gathered data from a sample of 200 male pre-service science teachers who were in their third year of study and had been invited to participate from a diverse range of teachers' colleges in Saudi Arabia. In total, 15 teachers' colleges were represented in the study, all utilizing the same national curriculum. Whereas all socio-economic family backgrounds were represented in the study, the majority of the pre-service science teachers were from families with earnings in the middle and upper segments of society. Commonly listed occupations of respondents' parents were teachers, lecturers, business people, and other skilled white-collar workers.

3.3 Research Setting

Teacher training in the Kingdom of Saudi Arabia (KSA) has been characterized by rapid development compared to other international settings. In 1979, the first diploma–level teachers' college was established in Riyadh. These colleges were known as middle colleges. In the seven to eight years after this date, numerous additional middle colleges of this size were founded throughout the Kingdom. In 1987, these diploma–level teachers' middle colleges were upgraded to colleges offering and awarding bachelor-degree level qualifications. In 1988, one year later, the majority of future teachers were studying in the college setting. The programs offered between this point in time and the following decade showed a dramatic improvement from earlier curricula and featured a greater focus on academic literature regarding education and best teaching practice. In 1998, information technology was implemented into the curriculum. Another development was the offering of mathematics and a range of science disciplines as majors to training teachers. Part of the reason for this addition was that prior to 1998, teachers graduating at the college level would only teach at the primary level. Teaching at the high school level was left to those who had completed university level studies. However, a new educational initiative set by the Ministry of Education wanted college level teachers to be able to teach at the secondary level as well. Between 2002 and 2007, more than 70,000 teachers completed teaching programs at the college level (Alriyadh Teacher's College, 2007)

In 2008, there was a royal order to open new colleges in each region and these colleges were to be amalgamated with new universities and the names of these colleges were changed to reflect the upgrade in becoming colleges of education or colleges of science adhering to university policy standards. As part of this change, the colleges were now under the jurisdiction of the newly formed Ministry of Higher Education. This new Ministry decreed that pre-service teachers were required to complete 87 designated modules of study. For science majors in this new learning environment, biology courses are a core unit in the program (Alriyadh Teacher's College, 2007).

3.4 Pilot Trial

The pilot trial's planning and results are discussed here. The pilot study helped to inform the researcher of the possible outcomes of the study on a small scale and whether the intended research design was flawed in any way. The pilot test also helped to provide the reader with all the required information before progressing on to methods associated with the main research. The pilot trial involved modifying the diagnostic test and Test of Science-Related Attitudes (TOSRA) questionnaire, translating it into Arabic and running trials with 20 pre-service teachers. The purpose of the pilot trial was to validate the modified Arabic versions of this questionnaire. As the original diagnostic test and TOSRA questionnaire were designed for Western students, with all statements in English, careful translations and back translations, as suggested by Brislin (1970, 1980), were carried out. The two instruments were translated into the Arabic language by the researcher, and then back translated by an English-speaking instructor not involved in the original translation. By comparing the original questionnaires with back-translated versions, it was possible to ensure that both versions conveyed the same meaning.

The pilot trial also assisted in checking the time required to complete each instrument, as well as to gain feedback on the layout and ease of reading the instruments. The researcher found no difficulties in the administration of the instruments to the class. The pre-service teachers had no problems in understanding the meaning of the Arabic statements on the instruments. The results suggested that the translated document presented no difficulties for the target group and that all the statements were clearly written.

3.5 Triangulation as Data-Gathering Methods

This study incorporated multiple methods to collect, describe and interpret the data. The use of multiple methods in a single study enhances the validity of research findings (Mathison, 1988) as providing rigour, breadth and depth to understanding of the phenomenon in question (Denzin & Lincoln, 2000). Multiple methods also allow for triangulation in the classic sense of seeking convergence of results (Creswell, 2005). Triangulation is an empirical strategy for improving the validity of evaluation and research findings. Triangulation often involves using interviews to validate questionnaires and questionnaires to validate interviews. Denzin (1997) defined triangulation as the use of different methods for gathering data with different samples, at different times, or in different places to compare different approaches to the same thing. The value of triangulation lies in providing evidence such that the researcher can construct good explanations of the social phenomena from which they arise (Mathison, 1988). According to Mathison (1988), the traditional aim of triangulation was to validate research. Contemporary understandings of triangulation are to provide additional information for the researcher that "must be rendered sensible" (Mathison, 1988, p.13). Detailed quantitative and qualitative data had been gathered throughout this study. Diagnostic test data provided highly detailed information about pre-service teachers' alternative conceptions. The TOSRA questionnaire provided information on the pre-service teachers' attitudes towards science. Semi-structured interviews provided information to confirm or disconfirm the diagnostic test and TOSRA results.

3.6 Data Collection

3.6.1 Quantitative Data

Quantitative data were collected through the use the diagnostic test and TOSRA.

3.6.1.1 Diagnostic Test

A conceptual diagnostic test aims to assess students' conceptual understanding of key ideas in a discipline, especially those that are prone to misconceptions. Hence, they are discipline-specific rather than generic. The format typically is multiple choice, so that a conceptual diagnostic test can be given efficiently to large numbers of students and be machine scored (Treagust, 1988). Diagnostic assessment is both formative and summative. Diagnostic assessment offers a different style of assessment. Generally, in the Gulf, assessment is characterized by regular examinations which quickly become routine to students (Ministry of Education Jordan, 2001). Diagnostic assessment offers a novel form of assessment. The second difference is that there are a variety of means to assess using diagnostic instruments. Teachers can keep a diary of daily activity in the class; teacher-student conversation can be used; teachers can check student work in situ, as students are working they can self-evaluate; and teachers can analyze the examination results beyond right and wrong answers but to look at the conceptions represented (Ministry of Education, Jordan, 2001).

To best understand prior ideas and to best diagnose learning, diagnostic assessment is increasingly implemented. While many teachers may already use similar informal activities, the crucial element of diagnostic assessment is the fact that there needs to be observations of responses and analysis of the underlying beliefs and understandings that guide the students' responses. This is the strength of the approach of Treagust (1988) in using two-tier multiple choice diagnostic instruments. The diagnostic test is a pen and paper instrument, which is reasonably simple for students to respond to and is quick and easy for teachers to assess (e.g., Chen, Lin, & Lin, 2002). In one study, Lin (2004) used a two tier diagnostic test to assess the understanding of high school students on flowering plant growth in Taiwan. Lin developed 13 two-tier multiple-choice items and administered the test to 477 high school students. The results of Lin's work were the identification of 19 misconceptions that are common among this sample group regarding flowering plant growth.

Diagnostic formative assessment methods make science teachers' pedagogy more effective (Bell & Cowie, 2001). Other researchers such as Wolf, Bixby, Glen, and Gardner (1991) have reported that the usual assessment procedures distort and narrow instruction, misrepresenting the nature of the subject; and they have asserted that these procedures do not provide valid measures of what students know and to provide no opportunity for students and teachers to be involved in discussions about the work being assessed. As Black and Wiliam (2001) commented, traditional assessment often serves social functions rather than pedagogical functions, which highlights the need for maximizing student learning to be re-positioned as the key goal of instruction in the Kingdom.

In this study, to determine the alternative conceptions of the students, a diagnostic test was used. The instrument consists of 17 questions divided into two groups. The first subject matter relates to diffusion and osmosis (questions 1 – 8) and the second subject matter concerns the concept of the particulate nature of matter (questions 9 – 17).

For the purposes of this study, the test layout was modified from the test of Odom and Barrow (1995), in three important ways. The first change was that the format for each question was shifted from the original approach, namely, 1a/1b - 12a/12b, to a more spaced out format where the questions are to be answered by choosing the right letter (the first tier) and the right number (the second tier) with the intention to make it easier for the students to complete the test, and for subsequent data analysis by the researcher. An example- item (1) -of the new layout is shown in Figure 3.1.

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:

1. The lack of a membrane means that osmosis and diffusion cannot occur.
2. There is movement of particles between regions of different concentrations.
3. The dye separates into small particles and mixes with water.

Figure 3.1 An example of modified layout for items in the diagnostic test used in this study.

The second deviation from Odom and Barrow's original test was that the number of questions was decreased from 12 items to 8 items. However, 9 questions assessing the students' understandings of the particulate nature of matter were added from Othman et al. (2008). The rationale and content of these questions is discussed in Chapter 1 (1.2 & 1.3). Finally, the third change was that the instrument was translated by a qualified Arabic translation specialist into Arabic language. As part of the quality assurance measures of the study, the diagnostic test was translated from English into Arabic and then back translated into English before being disseminated to the target group. The purpose of this back translation was to determine whether there were any inconsistencies in the language translation which would affect the outcomes of the study.

3.6.1.2 Test of Science-Related Attitudes (TOSRA)

A questionnaire comprises of a series of questions or statements to which individuals are asked to respond. Anderson and Arsenault (2004) gave a broad definition for questionnaires stating that they are "[A] set of written questions used to collect data from respondents" (p. 255). Ary and Jacob (1979), Wiersma (1986), and Wolf (1988) suggested that questionnaires are best used for collecting information about conditions, practices and opinions. Lovell and Lawson (1970), and Verma and Beard (1981) supported this, and also pointed out that questionnaires can be used to explore and determine attitudes and feelings, as well as opinions. Good and Hart (1952) and Oppenheim (1992) claimed that if the items in a questionnaire are easily understood by the respondent, then accurate relevant information will be obtained. Verma and Beard (1981) further advised that questionnaires should be brief and, if possible, allow for a variety of answers, rather than require dichotomous responses.

Regarding research instrument dissemination, Anderson and Arsenault (2004) suggested that there are three basic options that can be used to send out questionnaires. First, questionnaires can be printed and mailed to respondents. Respondents fill them out and mail them back. Second, through optical scanning, it is possible that questionnaires can be read by an optical scanner that picks up the responses automatically. This approach is only beneficial when there are hundreds of questionnaires. Smaller samples probably do not justify the printing and set-up costs. Third, electronic questionnaires via electronic mail (e-mail) are growing in popularity for professionals, organizations and individuals networked through the Internet. This form of questionnaire is designed on a computer and sent as a computer file to the subject via e-mail. The respondent receives the file, completes the questionnaire on his or her computer, and e-mails the file back to you. This is most useful for in-house surveys, such as within a school system.

The advantages of questionnaires over other methods of data collection have been discussed by a number of authors. Turney and Robb (1971) and Oppenheim (1992) mentioned that questionnaires can be distributed, at minimum effort and low cost, to large population samples, thereby ensuring good representativeness of the responses obtained. Also, as Verma and Beard (1981), and Slavin (1984) pointed out, questionnaire-based data are usually easier to process and analyze than data collected by other methods, for example, interviews, and hence provide better opportunity for comparisons between population subsamples to be made. Furthermore, Anderson and Arsenault (2004) mentioned that questionnaires enable the use of large number of questions where breadth is the focus over depth. As well, questionnaires often provide segments for individual comments and perspectives that are recorded in the respondent's own words. In addition, there are strengths that relate to the ease of using questionnaires. Questionnaires can be pre-made, there being tools available to help develop questionnaires. Researchers do not need to invest hours of time into designing something that has already been created. One such example, which makes this task easier, is Likert scale (Anderson & Arsenault, 2004). Likert (1932) created scales to cover a range of language to be used in creating research tools, and even provided guidelines for good questionnaire questions.

On the other hand, there are some limitations associated with the use of questionnaires. One limitation of questionnaires is when there is a lack of responses; the respondents may not answer all the questions or they may not answer them completely or correctly. This could happen when the respondent is careless, has faulty perceptions or is not interested in the topic. Some respondents deliberately tend towards more favourable or less favourable responses because of social influences (Nisbet & Entwistle, 1970). Creswell (2005) wrote about the dangers of a low response rate or response bias. Response bias occurs when the sample collected does not represent the target population (Creswell, 2005). Conversion of questionnaires answers into computer databases can also result in data entry errors (Anderson & Arsenault, 2004). Despite these limitations, questionnaires are widely used in research in education and other social sciences.

In this study, the third research question attempted to determine the pre-service teachers' attitudes towards science. In order to collect quantitative data that reflected the pre-service teachers' attitudes, the Test of Science-Related Attitude (TOSRA) used in this study was modified to include only three of the original scales of TOSRA—Attitude to Scientific inquiry, Adoption of Scientific Attitudes and Enjoyment of Science Lessons. The selection of these scales was made as they contained items which most directly address the target of identifying the pre-existing teachers' attitudes. The TOSRA contained 30 items altogether, with ten items in each of three scales. The same questionnaire as that used in the pilot trial was used in the main study. The item scoring in each scale of the TOSRA employed a five-point Likert response scale where each item is responded to with alternatives of "Strongly Agree", "Agree", "Not Sure", "Disagree" and "Strongly Disagree". The three scales of TOSRA and sample items, one in each scale, are given in Table 3.1. The complete instrument can be found in Appendices (B).

Table 3.1

Scale Description and Sample Items of the Test of Science-Related Attitudes (TOSRA)

Scale Name	Klopfer's (1971) Classification	Sample item
Attitude to scientific Inquiry	Acceptance of scientific inquiry as a way of thought	I would prefer to find out why something happens by doing an experiment than by being told. (+)
Adoption of Science Attitudes	Adoption of 'science attitudes'	I dislike listening to other people's opinions (-)
Enjoyment of Science Lessons	Enjoyment of science learning experiences	Science lessons are fun (+)

Note. Adapted from Fraser (1981). Items designated (+) are scored 1, 2, 3, 4 and 5, respectively, for the responses Strongly Agree, Agree, Not Sure, Disagree and Strongly Disagree. Items designated (-) are scored in reverse manner. Omitted or invalid responses are scored 3.

While maintaining the same content, the TOSRA was translated into Arabic for easier understanding by the respondents. Also, the answer sheet was added to the question sheet to further make it easier for the respondents.

3.6.2 Qualitative Data: Semi-Structured Interviews

Qualitative data were collected as a means of responding to the research questions posed in this study. The sources of these qualitative data included semi-structured interviews. Interviews are important tools to discover participants' feelings and to probe further ideas or statements that are vague (Merriam, 1998). An interview is defined as “a specialized form of communication between people for a specific purpose associated with some agreed subject matter” (Anderson & Arsenault, 2004, p. 190). The interview is probably the most widely used method of data collection in educational research. Interviews can be conducted on all participants by all types of interviewers and they can range from informal incidental sources of data to the primary source of information used in a research study. When used with care and skill, interviews are an incomparably rich source of data (Anderson & Arsenault, 2004). According to Fontana and Frey (2000), interviews provide insights gained by talking to the participants and provide a flexible method of data collection.

Interviews can be both structured and semi-structured, providing information that is considered authentic and reliable depending largely on the situation (Lewin, 1990). The structured interview format involves control, reliability and speed where the investigator has maximum control over what takes place in the interview (Smith, 1995). With the semi-structured interview, the investigator has a set of questions for an interview schedule but the interview will be guided by the schedule rather than dictated by it (Smith, 1995). Semi-structured interviews allow the respondents to be perceived as experts on the subject and should therefore be allowed maximum opportunity to tell their own story. A semi-structured interview is an attempt to establish rapport with the respondent, the ordering of questions is less important, the interviewer is freer to probe interesting areas that arise, and the interview can follow the respondent’s interests (Fontana & Frey, 2000).

In conducting the interviews, the format suggested by Fontana and Frey (2000) was followed. Semi-structured interviews were maintained so that there was a casual atmosphere and the interviewees were engaged in real conversations. Semi-structured interviews were conducted with student teachers who had already taken the diagnostic test. Each of the student teachers was interviewed individually in a place and at a time convenient to them. The interview transcript was written in Arabic language, and then translated to English language by the researcher. An English-speaking instructor checked the translation from Arabic to English. Each interview lasted from 10 to 20 minutes, depending on how much the interviewee wished to discuss.

3.7 Data Analysis Procedures and Interpretation

This section is about analyzing the collected data and attempting to use these data to determine the answers to the research questions posed at the inception of the study. As a means of accomplishing this task, the researcher studied the results from both the quantitative data and the qualitative data analyses.

3.7.1 Quantitative Analysis

Quantitative data were analyzed statistically by using the Statistical Packages for Social Science (SPSS) computer software for Windows 17.0. The data analysed were grouped on an individual basis and a group basis. Alpha reliability and discriminant validity values for the three scales of TOSRA were obtained from the SPSS package. Descriptive, statistical and correlation analyses on all data provided by the pre-service teachers were performed with this program.

3.7.1.1 Reliability coefficients (internal consistency reliability)

Reliability coefficients are a measure of the consistency of a test (Wiersma, 1986). In interpreting reliability coefficients, McMillan and Schumacher (1993) indicated that an acceptable range for most instruments is 0.70 to 0.90 and 0.5 is acceptable in exploratory research. However, these authors suggested that as reliability is essentially a function of the nature of the trait being examined, measures of achievement should generally have high reliabilities. Furthermore, high reliabilities are required if results are used to make decisions about individuals; whereas studies of groups can tolerate a lower reliability. In the development of a questionnaire, it is necessary to establish that each item in a scale assesses a common construct. If this is the case, then the scale is referred to as being homogenous or having internal consistency. Reliability of the conceptual questionnaire was used to confirm that the items are reliable for this group of Saudi pre-service teachers. The internal consistency of each scale in the TOSRA was utilized for this role.

3.7.1.2 Discriminant validity

Discriminant validity assesses the extent to which a scale is unique in the dimension that it covers (i.e., the concept is not included in another scale of the instrument) (Munro, 2005). As a convenient index of the discriminant validity of raw scale scores, the mean magnitude of the correlation of one scale with other scales in the

TOSRA was calculated. This was conducted with the three selected scales from TOSRA.

3.7.1.3 Mean and standard deviation

The mean is the sum of the scores in a distribution divided by the number of scores in the distribution (Wiersma, 1986). The mean is the most commonly used measure of central tendency which is the arithmetic average of a group of scores. In contrary, the standard deviation is the most commonly used measure of variation, which is the average distance of all the scores in the distribution from the mean or central point of the distribution. It is a measure of variability that is the positive square root of the variance (Wiersma, 1986). In this study, mean scores of two conceptual categories (diffusion and osmosis, and the particulate nature of matter) were calculated. Comparing the computed mean scores between the two conceptual categories indicated the extent to which student teachers were able to relate their understanding of the particulate nature of matter to diffusion and osmosis concepts. The mean and standard deviation of each scale from the TOSRA were similarly computed.

3.7.1.4 Correlations and regression analysis

A correlation coefficient is "a statistic that measures the direction and magnitude of the relationship between two variables" (Anderson & Arsenault, 2004, p. 250). It not only describes the relationship between variables but also allows making predictions from one variable to another. Correlations between variables indicate that when one variable is present at a certain level, the other also tends to be present at a certain level (Jackson, 2006). The correlation coefficients may range from +1.00 through 0.00 to -1.00. A +1.00 indicates a perfect positive relationship, 0.00 indicates no relationship, and -1.00 indicates a perfect negative relationship (Munro, 2005). The most commonly used correlation coefficient is the *simple correlation* (*Pearson product moment correlation coefficient)* referred to as *r*. Pearson's *r* is used for data measured on an interval scale of measurement (Jackson, 2006). *Multiple correlation* (R) is the relationship between one dependent variable and a weighted composite of independent variables. A multiple correlation can range from 0 to 1. There are no negative Rs because the method of least squares is used to calculate R, and squaring numbers eliminates negatives (Munro, 2005). Advanced correlational techniques are called *regression analysis* that is, according to Jackson (2006), a procedure that allows multiple correlation to predict an individual's score on one variable based on knowing one or more other variables. A more advanced use of regression analysis is known as *multiple regression analysis* (β) which involves combining several predictor variables in a single regression equation. With multiple regression analysis, a researcher can assess the effects of multiple predictor variables (rather than a single predictor variable) on the dependent measure (Munro, 2005). Anderson and Arsenault (2004) defined the dependent variable as a "variable that is 'thought' to be affected/influenced by a treatment or intervention" (p. 251) and the independent variable as "a variable which is believed to cause or influence a dependent variable" (p. 253). To explore the relationship between pre-service teachers' conceptual understanding and pre-service teachers' attitude towards science, Pearson correlation and multiple regression analysis were calculated.

3.7.2 Qualitative Analysis

Analysis and interpretation is a simultaneous activity in qualitative research. Analysis begins with the first observation, the first document read, and the first interview (Merriam, 1988). According to Lauer and Asher (1988), "the most crucial task of a case study, as well as other types of qualitative and quantitative research, is the identification of important variables in the data" (p.26). Furthermore, in qualitative analysis, data are recorded as text and then analysis transforms them into new text (Nielsen, 1994). The researcher regards this type of data as seeking patterns of developing issues, triangulating important observations and bases for interpretations, seeking alternative interpretations to pursue, and developing assertions about each case (Stake, 2000). For the nature of this study, the interpretive analysis of the semi-structured interviews was used.

3.7.3 Interpretive Analysis

Interpretive research focuses on a specific social situation or phenomenon. It is descriptive in nature and offers insights into the phenomenon being studied (Merriam, 1988). The researcher is expected to be close to the phenomena and the participants in the study and, consequently, establish and maintain trust throughout the study. In Merriam's opinion, a study which implements an interpretive approach should be a thick description of the phenomenon under study. These rich descriptive data are used to develop conceptual categories or to illustrate or support theoretical assumptions held prior to data collection. Gallagher (1991) described interpretive research as a "tool for helping educators in universities gain a better understanding of the community into which educational products move". By products, he meant not only teachers but also programs and models for teaching and learning, and the materials that are produced to support teachers' work with students. Furthermore, interpretive research is a tool for helping all those who are teaching regardless of the level (university, secondary school, intermediate school or primary school) to gain a better understanding of the many facets of teaching and learning.

In the present study, an interpretive approach was employed to gain an in-depth understanding of the complexity of the qualitative data obtained from semi-structured interviews. The semi-structured interviews were analyzed by content analysis and organization of the information into categories. This information from an analysis of the semi-structured interviews were used to support or reject the quantitative analysis of the diagnostic conceptual test and TOSRA. Consequently, the information from the qualitative analysis was melded and examined with the results of quantitative data, and links were clarified and established to support or refute the research questions presented in Chapter 1.

3.8 The Quality Criteria of the Study

Data analysis — that is meticulously done based on clearly articulated theories and responsive to the research questions — must also yield results that are meaningful to the people for whom they are intended and described in a language they understand. It has been argued by Denzin and Lincoln (1998) that there is no single interpretive truth and that criteria that are used for evaluation purposes should stress the "situated, relational, and textural structures of the ethnographic experience" (p. 30). Constructivists have argued that traditional and positivist or post-positivist research paradigms requiring validity and reliability checks are not relevant for an interpretive study (Denzin & Lincoln, 1998). Where positivism concerns itself with validity, reliability and objectivity, the constructivist paradigm replaces these issues with credibility, dependability, confirmability, and authenticity, respectively. Thus, in order to satisfy questions of rigour in this research, the following review describes the criteria for judging the soundness of the qualitative data.

3.8.1 Credibility as Validity

Ascertaining validity of qualitative data involves issues of truth and correctness of a statement (Kvale, 1996) and accurate measurement as intended. Guba and Lincoln (1989) preferred to use the term *credibility* to *internal validity* and defined it within the positivist paradigm as "the extent to which variations in an outcome or dependent variable can be attributed to controlled variation in an independent variable "(Guba & Lincoln, 1989, p. 234). Cohen, Manion, and Morrison (2005) contended that the findings must accurately describe the phenomena being researched. Guba and Lincoln (1989) suggested that there were six basic strategies that could be used to ensure internal validity, namely, prolonged engagement at the site of inquiry, triangulation, persistent observation, peer debriefing, negative case analysis and member checking. These six criteria are in agreement with those proposed by Merriam (1990): (1) triangulation which includes using multiple data sources or multiple methods to confirm emerging findings; (2) member checks, that is, taking data and interpretations back to the people from whom they were derived and asking them if results are plausible; (3) long-term observation at the research site or repeated observation of the same phenomena; (4) peer examination which implies asking colleagues to comment on the findings as they emerge; (5) participatory modes of research involving participants in all phases of research; and (6) researcher's biases which can be addressed by clarifying the researcher's assumptions, worldview and theoretical orientations at the outset of the study.

In this research, credibility was addressed in a way consistent with both Guba and Lincoln's (1989) and Merriam's (1990) constructivist strategies. In terms of triangulation, this study used a number of data sources and methods, which included a diagnostic test, a questionnaire, and interviews. Peer examination took place through discussion with the thesis supervisor, some of the SMEC staff, as well as with fellow doctoral students on a regular basis. As well, this study included member checks through continued interaction with pre-service teachers that resulted in the participation of those involved in this research.

3.8.2 External Validity as Transferability

External validity is concerned with the extent to which the findings of the study can be applied to other situations (Merriam, 1998). Cohen et al. (2005) referred to external validity as the degree to which the results can be generalized to a wider population, cases or situation. Guba and Lincoln (1989) preferred to use the term transferability to generalizability, as transferability requires that sufficient descriptive data are made available by the original investigator so that a person can make similar judgements in deciding to apply or transfer the findings to a new context. In this regard, transferability requires thick descriptions which the researcher provided for the settings of the teacher colleges and the pre-service teachers, including extensive details of time, place and context of the investigation.

3.8.3 Reliability as Dependability

Reliability is concerned with the stability of the data over time or the extent to which findings may be replicated (Guba & Lincoln, 1989; Merriam, 1998). Quantitative research assumes the possibility of replication. With the emergent nature of qualitative research or case study, the traditional meaning of reliability becomes somewhat strained when using a constructivist approach to teaching and learning. To ensure dependable results, Merriam (1998) suggested triangulating data and method, and providing an audit trail. The use of triangulation was discussed under credibility. An audit trail, according to Guba and Lincoln (1989), is a process that is established, trackable and documentable so that the analysis of the collected data can be confirmed. How the quantitative and qualitative data were collected has been described in detail under Section 3.6 such that the procedures can be followed by other researchers to carry out a similar study.

3.8.4 Objectivity as Confirmability

Guba and Lincoln (1989) proposed the concept of confirmability as a parallel notion for objectivity which is concerned with “assuring that the data, interpretations and outcomes of inquiries are rooted in contexts and persons apart from the evaluator” (p. 243). To confirm the way in which the data were collected in this study, the researcher has shown how the audit trail that traces the conversion of data into findings and demonstrated that the findings were not simply part of the researcher’s imagination. Consequently, this chapter on research methodology establishes the confirmability and dependability audit so the process of data collection is clear and explicit, providing a level of details that would enable other researchers to carry out a similar study.

3.8.5 Validity as Authenticity

The authenticity criteria are the hallmark of a trustworthy and rigorous enquiry and include fairness, educative authenticity and catalytic authenticity (Guba & Lincoln, 1989, 1994). Fairness is an attempt to prevent the participants of the study from being marginalized and to ensure that all voices in the enquiry are represented in the text. This research included the perspectives and voices of several of the pre-service teacher participants. Educative authenticity is the criteria for determining a level of awareness by the researcher and participants for research and social purpose.

3.9 Ethical Issues

Review of the literature on educational research highlights that ethical issues may arise from the nature of the research project itself, the context of the research, the procedures to be adopted, the methods of data collection, the nature of the participants, the type of data collected, and even what is to be done with the data (Anderson & Arsenault, 2004; Cohen et al., 2005; Creswall, 2005). Caven (1977) defined ethics as matter sensitive to other people's rights based on principles. Others have commented that ethical research is research that does not harm human beings physically or psychologically (Frankel & Wallen, 2003). In this research, important ethical issues were addressed as reported next in this section.

In this study, the main ethical issue to be addressed was to maintain the anonymity of the pre-service teachers (Anderson & Arsenault, 2004; Creswell, 2005). Gall, Borg, and Gall (1996) suggested that the best approach is to strictly minimize the number of individuals who are identifiable as research participants. This project identified sensitive information regarding the pre-service teachers' conceptions on diffusion and osmosis. This information could be damaging because the pre-service teachers prided themselves on knowing the right answers, in other words, having the right conceptions. Therefore, it was crucial to de-identify all of the participating pre-service teachers and also to ensure that their respective teachers' colleges are de-identified.

Another reason that the pre-service teachers' responses have to be de-identified relates to the Test of Science-Related Attitudes. In this test, the pre-service teachers reveal their attitudes towards science. These results are highly useful for an educational planning viewpoint. However, again, these results can be damaging. If it is found that there is a trend of the pre-service teachers having unprofessional attitudes, this looks unfavourable for them and their respective colleagues. Therefore, again, the need for de-identification is stressed.

The third ethical issue is how the participants were chosen. Creswell (2005) writes that researchers must respect the sites where the research takes place. To do this, the respective deans of the teachers' colleges were contacted to receive authority. Moreover, the researcher attempted to gather data from a range of teachers' colleges in order to gain a representative sample. Also, the deans were informed that the research had gained ethical clearance from Curtin University of Technology and that the data would be securely stored for a period of five years at Curtin University, and then securely shredded.

Finally, the data needs to be presented in a respectful way and with non-discriminatory language (Creswell, 2005). Reporting the findings appropriately entails reporting the research fully and honestly. Therefore, the researcher needs to ensure the accuracy and fullness of the results. Merriam (1990) writes that the onus of ethical dissemination of the research lies with the principal researcher.

However, there are risks of implementing such as a study. There is an immense pressure on the teachers in the Gulf. Government support programs such as The Education Development Draft of the Gulf Cooperation Council implemented by a decision issued by the twenty-fourth Gulf Cooperation Council session that aims at making teachers more accountable (Gulf Cooperation Council, 2002). The draft stipulates creating a unified plan of the appropriate programs and projects to achieve the comprehensive development of education. Many of the innovations were put into place by His Royal Highness King Abdullah Bin Abdul Aziz, and his Advisory Body. These innovations are an attempt to improve teaching and learning but place pressure on the classroom teachers to produce measurable results.

One risk is exposing a low level of correct pre-service teacher conceptions about diffusion and osmosis. As part of these implementations, quality control is important before, during and after fulfilling each program. However, until now using traditional assessment, it has been hard to measure the effectiveness of these educational implementations. With diagnostic assessment, the results can be more accurate, and therefore, have more potential to defame those with lower results. This negative impact risk will be managed by the researcher by means of providing additional in-service to the lecturers of the pre-service teachers.

Another risk of this research is causing a swing from a humanities-based curriculum to a science-based curriculum. Saudi teacher colleges espouse for "preparing the Arab Muslim to be a good, productive, lifelong learning citizen". According to government documentation, such a citizen is committed to the Arab and Islamic values in thinking, manners, and behaviour in life including dealing with others in fairness, tolerance and with mutual respects. As diagnostic tests may expose weaknesses in conceptual knowledge and larger weaknesses in science knowledge in general, there is a risk that this research project threatens to magnify the focus on science awareness at the expense of important humanities-based subjects. Anderson and Arsenault (2004) commented on this risk labelling it a "risk to cultural and proprietary values" (p. 25).

Finally, another risk is assessing pre-service teachers' science aptitudes without testing their laboratory skills. Laboratory work and experiments are an important component of the education development draft (Kuwait, Shawwal 1424 AH, December 2003). However, they are not tested through this research project. This situation may have a negative impact of skewing the results or giving invalid results, which do not show pre-service teachers' practical science aptitudes. This limitation could be addressed by collecting data from other pre-service teacher samples which do include this aspect (Anderson & Arsenault, 2004).

3.10 Summary of Chapter

This chapter describes the participants of the study, the research settings, both historical and professional, and the research methods employed in the study. Part of the detailed methodology is reported with the validation results of the pilot study and adaptations that were made to the assessment in order to make the instruments easier for participants to complete and later for the researcher to analyze. This chapter finally describes the methods of statistical analysis of the data as well as the quality standards imposed on the study, which focused on the rigorous control of qualitative data analysis and presentation.

CHAPTER FOUR

A PILOT STUDY

4.1 Introduction

Presently, one of the major efforts in Saudi Arabia is to increase the number of science teachers in the country. Subsequently, programs have been designed to improve teachers' proficiency in the use of instructional strategies in teaching science. One of the crucial factors is to increase the number of science teachers who have a thorough understanding of science concepts and fundamentals.

Science is important in today's society but understanding science is a complicated task. As a result, pre-service programs face enormous challenges towards making progress in teachers' understanding of science and the pedagogies that contrast with the lecture method. These understandings of pre-service teachers are essential in order to facilitate their students' understanding of concepts related to phenomena in students' everyday experiences.

Diffusion and osmosis are important concepts in biology, and understanding of particulate nature of matter is necessary for understanding concepts in chemistry and biology. Students therefore need to be given time to develop an understanding of these particularly important topics in science. Hence, teachers need to acquire the necessary instructional skills to facilitate students' understanding of these important concepts in biology and chemistry.

The main purpose of this pilot study was to assess Saudi Arabian pre-service science teachers' understanding of diffusion, osmosis and the particulate nature of matter as well as their attitude towards science. At the same time, the pilot study enabled the researcher to ascertain the validity of the instruments used and potential problems related to pre-service teachers' understanding of the items in the two-tier diagnostic instrument prior to undertaking the study on a larger scale.

4.2 Methodology

4.2.1 Sample

For the pilot study, the instruments were administered to 20 pre-service science teachers from the Al-Russ Teacher's College which is located in the middle of Saudi Arabia, and the Riyadh Teachers College in the capital of Saudi Arabia. The instruments were then administered to a larger more diverse sample of 200 pre-service teachers.

4.2.2 Diagnostic Test and Attitudes

A two-tier multiple-choice diagnostic instrument investigating Saudi Arabian pre-service science teachers understanding of diffusion, osmosis and particulate nature of matter was used in this study. This diagnostic test consisted of 21 two-tier multiple-choice items of which 12 items involved concepts related to diffusion and osmosis (Odom & Barrow, 1995). The remaining nine items related involved concepts related to the particulate nature of matter (Othman et al., 2008). The first tier of the items consisted of content questions with two, or three or four choices. The second tier consisted of three or four possible reasons for the first tier, namely two or three scientifically inappropriate reasons and one scientifically appropriate reason. The inappropriate reasons were based on misconceptions that were identified when the multiple-choice test with free response reasons was administered to pre-service teachers as well as from interview sessions with these teachers. An example of an item involving diffusion is given in Figure 4.1.

Item 2
During the process of diffusion, particles will generally move from:
 a. high to low concentrations
 b. low to high concentrations
The reason for my answer is because:
1. There are too many particles crowded into one area; therefore, they move to an area with more room.
2. Particles in areas of greater concentration are more likely to bounce towards other areas.
3. The particles tend to move until the two areas are isotonic, and then the particles stop moving.
4. There is a greater chance of the particles repelling each other.

Figure 4.1. Item 2 in the two-tier multiple-choice diagnostic instrument (Odom & Barrow, 1995).

The Test of Science-Related Attitude (TOSRA), first developed by Fraser (1981), involved a Likert-type questionnaire, which enabled pre-service science teachers to demonstrate their attitudes towards science. As described in Section 3.6.1.2, only three of the original TOSRA consists of seven scales, were used in this study: Attitude to scientific inquiry, adoption of scientific attitudes; and enjoyment of science lessons, each of which contains 10 items. The three TOSRA scales used in the study with an example statement item from each one are shown in Table 4.1.

Table 4.1

Three TOSRA Scales Used in the Study and an Example Statement Item from Each Scale (Fraser, 1981)

Scale name	Attitude to scientific inquiry	Adoption of scientific attitudes	Enjoyment of science lessons
Example statement item from scale	"I would prefer to find out why something happens by doing an experiment than by being told."	"I enjoy reading about things which disagree with my previous ideas."	"Science lessons are fun"

4.2.3 Statistical Analysis

Quantitative statistics were performed using the Statistical Package for the Social Sciences (SPSS) version 17 (Hashem, 2004).

4.3 Results

The percentages of students who correctly answered the first tier only and both tiers of the items in the diagnostic test on diffusion, osmosis and the particulate nature of matter are presented in Table 4.2. Figure 4.2 is a graphical representation of the percentage of correct responses to each item.

Table 4.2

Percentage of Students Correctly Answering the First Tier Only and Both Tiers of the Items on Diffusion, Osmosis and the Particulate Nature of Matter (n=20)

Item	Percentage of students correctly answering		Item	Percentage of students correctly answering	
	First tier	Both tiers		First tier	Both tiers
1	90.0	15.0	12	90.0	42.0
2	90.0	35.0	13	55.0	30.0
3	75.5	10.0	14	30.0	00.0
4	80.0	60.0	15	15.0	05.0
5	35.0	25.0	16	85.0	15.0
6	75.0	60.0	17	20.0	20.0
7	70.0	50.0	18	60.0	45.0
8	30.0	15.0	19	75.0	40.0
9	55.0	30.0	20	45.0	10.0
10	90.0	30.0	21	80.0	25.0
11	15.0	00.0			

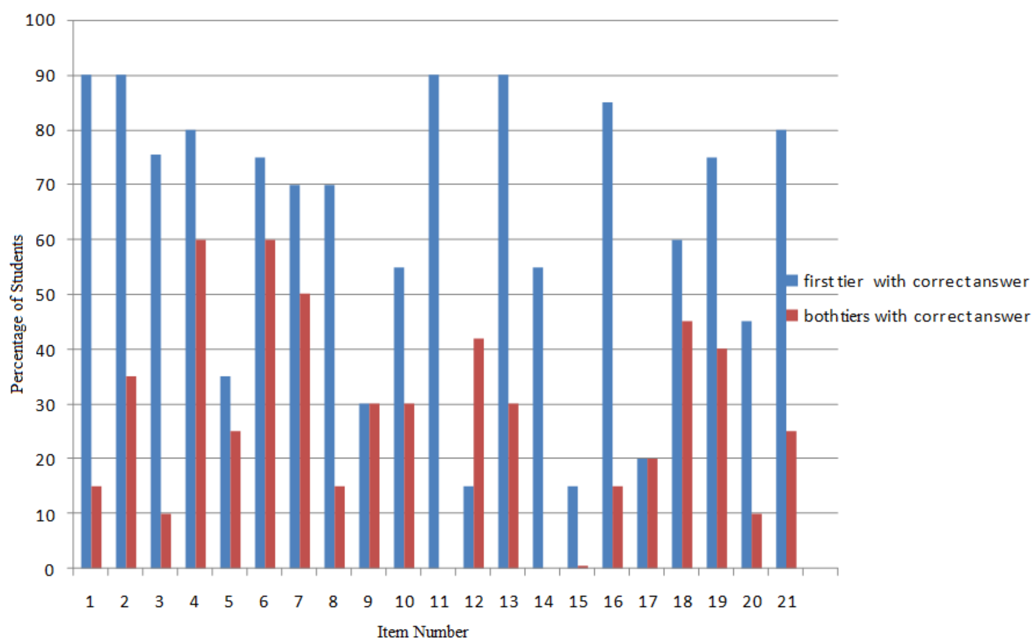


Figure 4.2. A pictorial view of the percentage of each item correctly answered (*n*=20)

It can be seen from Table 4.2 that for the first tier of the test items, the percentage range of correct answers was 15% - 90%. With both tiers combined, the percentage of correct answers was reduced, ranging from 0% - 60%. This trend is very likely an indication of the pre-service teachers memorizing facts without real understanding of the concepts involved. In addition, the percentage of correct answers to the first tier of five of the 21 items was relatively low (15 – 30%). The variations in the percentage of correctly answered questions for both tiers are summarized in Table 4.3.

Table 4.3

Means and Standard Deviations of the Percentage of Correctly Answered Questions for the Items in the Diagnostic Instrument (Correct to 2 Decimal Places) (n=20)

	Tier 1	Tier 2	Both tiers
Mean	60.02	26.76	43.39
Standard Deviation	26.61	18.06	22.33

4.4 Difficulty Index and Discrimination Index

To determine the level of difficulty of the items, a difficulty index analysis of the items was computed. In this study, the *item difficulty index (P)* refers to the percentage of the total number of correct responses to the test item. It is calculated by the following formula: $P = R/T$, where R is the number of correct responses and T is the total number of responses (i.e., correct + incorrect + blank responses). Thus, the lower the values the difficulty index an item has, the greater will be its difficulty. The value of the difficulty index can indicate whether the item needs to be retained, revised, or rejected. The ideal test should contain items whose difficulty indices range from 0.41 to 0.60. However, for most teacher-made tests, a difficulty index in the range of 0.30 to 0.70 is considered acceptable. Too easy or too difficult items should not be included in the final test. The levels of difficulty and the corresponding items in the diagnostic instrument are summarized in Table 4.4.

Table 4.4

Difficulty Index Scale for the Diagnostic Instrument (n=20)

Category	Scale	Items in the diagnostic test
Very difficult	0.00 – 0.20	1,3,5,8,11,14,15,17,19,20
Difficult	0.21 – 0.40	2,9,10,13,16,21
Optimum difficulty	0.41 – 0.60	4,6,7,18
Easy	0.61 – 0.80	12
Very easy	0.81 – 1.00	-

It can be seen in Figure 4.2 that questions with low difficulty index were answered correctly by most of the students while students had difficulty in answering questions with high difficulty index.

Another criterion that indicates the suitability of an item is the discriminating power of an item. The item discrimination index (D) measures the difference between the percentage of students in the upper group (i.e., the top 27% scorers), who chose the correct response for the item, and the percentage of those in the lower group (i.e. the bottom 27% scorers), who chose the correct response (Sim & Rasiah, 2006).

A high discrimination index indicates that the item discriminates well between high- achieving and lower-achieving students (Backhoff et al., 2000). Usually, a good item discriminates high-achieving students from the low-achieving ones. The following scale is used to interpret the indiscrimination index values. The levels of discrimination and the corresponding items in the diagnostic instrument are summarized in Table 4.5.

Table 4.5

Discrimination Index Scale for the Diagnostic Instrument (n=20)

Category	Scale	Items in the diagnostic test
Questionable item	Less than 0.10	3,11
Not discriminating	0.11 – 0.20	8,9,15
Moderately discriminating	0.21 – 0.30	4,6,12,14,16,17,18,20
Discriminating	0.31 – 0.40	1,2,7,10,13,19,21
Very discriminating	0.41 – 1.00	5

The values of the difficulty index (P) and the discrimination index (D) for the 21 items are summarized in Table 4.6. It can be seen that the Difficulty index ranged from as low as 0 to 0.05 ("extremely difficult") to as high of 0.75 ("easy") suggesting the presence of a wide range of difficulty of the items. The index 0.75 may be too easy for an achievement test however; this wide range was appropriate to diagnose how many students had different kinds of alternative conceptions.

As shown in Table 4.6, the discrimination index fell in the range of 0.01 to 0.4. A value of 0.2 was established as a minimum without the need for further revision of the test items (Odom & Barrow, 1995). Using this parameter, items numbered 3, 8, 9 and 11 with discrimination indices of less than 0.2 need further revision.

It is also interesting to note that the item with the lowest difficulty index (i.e., Item 12 with P = 0.75) did not have corresponding highest value of discrimination index. Similarly Item 6, which had a moderate difficulty level (.60), provided a moderate discrimination level (0.27). Item 1 has a very high difficulty index (P = 0.15) and high discrimination index (D = 0.40) and can be considered the best item in this assessment. Furthermore, the overall assessment (as shown in Table 4.6) has a positive mean discrimination index (between 0.01 and 0.40). This suggests that students who obtained a high total score chose the correct response for a specific item more often than the students who had a lower overall score.

Table 4.6

Difficulty Index (P) and Discrimination Index (D) for 21 Items

Item no.	Difficulty index	Discrimination index
1	0.15	0.40
2	0.35	0.32
3	0.10	0.01
4	0.60	0.20
5	0.20	0.43
6	0.60	0.27
7	0.50	0.35
8	0.15	0.10
9	0.30	0.14
10	0.30	0.31
11	0.00	0.09
12	0.75	0.25
13	0.30	0.35
14	0.00	0.28
15	0.05	0.15
16	0.30	0.26
17	0.20	0.24
18	0.45	0.25
19	0.05	0.31
20	0.10	0.27
21	0.25	0.34
Mean	0.27	0.37

Table 4.6 and graphical representation of the difficulty and discrimination indexes in Figure 4.3 suggest that the Items 1 and 5 fall under the category of very difficult and very discriminating whereas Items 2,10,13,14,16,17,18,19,20 and 21 are

very difficult, difficult and optimally difficult; and their discrimination powers are discriminating and moderately discriminating. The percentage of very difficult and very discriminating items is 11% whereas the percentage of others after ignoring the easy and not discriminating is 58%. The percentage of easy and not discriminating items remains at about to 21%. Based on the difficult and discriminative nature of the items it can be said that the items prepared for this test were satisfactory.

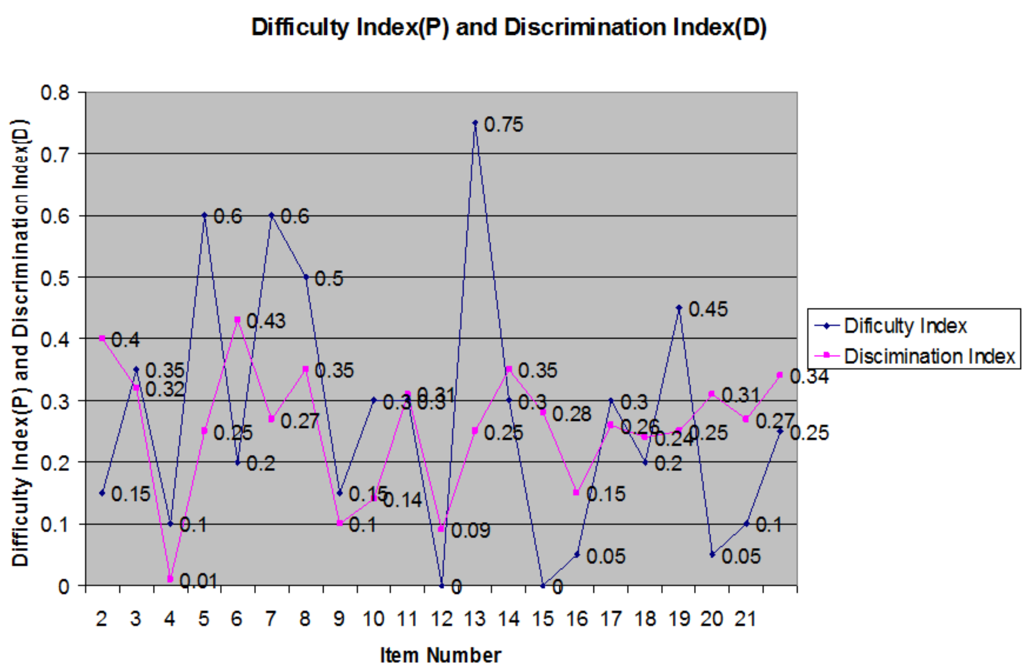


Figure 4.3. Difficulty Index and Discrimination Index for 21 Items in DOPT Diagnostic Instrument.

The instrument was not intended to have a normative function although the intended function of this instrument was to ascertain the conceptual level at which students are working. The internal consistency refers to the capacity of the instrument's different items of a scale to accurately measure the quality that the scale is intended to measure. The items here seek to determine the students' level of understanding of diffusion and osmosis and the particulate nature of matter. For the 21 items together for the whole instrument, the internal consistency was found to be 0.56.

4.5 Reliability and Validity of the Test of Science-Related Attitude (TOSRA)

Validation of an instrument is an essential step in any research that involves statistical analysis of the data and depends on the accuracy of the data collected to make meaningful conclusions. A significant part of this study was the assessment of quantitative data collected by the administration of the TOSRA to the student teachers involved in the pilot study.

However, even though students from different countries including Saudi Arabia may exhibit similar attitudes it cannot be assumed that an instrument shown to be valid beyond Saudi Arabia would necessarily apply to Saudi Arabian students. Therefore, there was a need to validate TOSRA before any results from this research could be considered valid.

The TOSRA questionnaire was administered to the 20 pre-service teachers who responded to the two-tier diagnostic instrument. The Cronbach alpha coefficient (Cronbach, 1951) was used to assess the internal consistency reliability of the scales, and securing evidence that can be used to support the instrument's construct validation. The internal consistency was determined on the 30 items in the TOSRA representing students' views of science and found to be 0.67 (as shown in Table 4.7). This compares well with other studies, for example, the values of the internal consistency reliability of the TOSRA reported by Fraser (1977b) were in the range 0.69 to 0.84.

Table 4.7

Internal Consistency (Cronbach Alpha Reliability Coefficient) for Each Scale of the TOSRA (n=20)

Scale	Cronbach alpha	No. of Items
Adoption of scientific attitudes	0.56	10
Enjoyment of science lesson	0.74	10
Attitude to scientific inquiry	0.72	10

4.6 Conclusion

This pilot study provides evidence that the pre-service science teachers in Saudi Arabia displayed limited understandings of the concepts related to diffusion, osmosis and the particulate nature of matter. The diagnostic tests developed for diffusion, osmosis and particulate nature of matter was successful in providing a feasible approach for evaluating pre-service teachers' understanding and for identifying alternative conception that are held by them. The results from the pilot study indicated that the instrument is able to diagnose the extent of the pre-service teachers' understanding.

The pilot study also confirmed the reliability and validity of the TOSRA instrument when used with the pre-service science teachers. The analysis of data in the pilot study suggested some items in the diagnostic instrument needed to be retained, revised or removed in the test developed by the researcher. Item analysis indicated the presence of an overall positive discrimination index and suggests that students who obtained a high total score chose the correct response for a specific item more often than the students who had a lower overall score.

CHAPTER FIVE

PRESENTATION OF DATA, ANALYSIS AND RESULTS

5.1 Introduction

This chapter presents the project's data, an analysis of the data and explanations for the results. In Section 5.2, the results of the analysis of the data for the 17 items in the Diffusion, Osmosis and Particle Theory (Particulate Nature of Matter) (DOPT) two-tier diagnostic instrument are presented and discussed. In Section 5.3, the alternative conceptions held by more than 10% of the pre-service science teachers are discussed. In Section 5.4, associations between the diffusion, osmosis and the particulate nature of matter are presented.

5.2 Analysis of the Results

In total, 192 pre-service science teachers, from 15 teachers' colleges, completed the DOPT diagnostic instrument. A response for each DOPT item was only considered completely correct if a pre-service science teacher first selected the correct answer from three or four content options in the first tier and then also selected the most precise justification from a range of three or four reason options in the second tier. These data are presented in Table 5.1. The asterisk next to each percentage indicates the correct content option and the best reason option. The text in bold in the first row indicates an alternative conception held by more than 10% of the pre-service teachers. The percentages of students who provided the correct responses to both tiers of the 17 items in the DOPT diagnostic instrument are shown in Figure 5.1.

As shown in Table 5.2, for the first tier in the test items, the range of correct responses was 65.6% to 93.8 %. With both tiers combined, the range of correct responses was reduced to 57.3% to 84.6% for the first eight items (diffusion and osmosis). Correct responses to the items about the particle theory in the test (i.e., Items 9-17) ranged from 52.4% to 88.5% in the first tier; in the second tier the correct responses ranged from 41% to 56%. The percentages of students in the study with alternative conceptions for reasons 1, 2 and 3 with content options A, B and C are shown in Figure 5.2.

Table 5.1

Percentage of Students Who Provided Responses to Both Tiers of Each Item in DOPT Diagnostic Instrument (n=192)

Item	Content option	Reason option			
		(1)	(2)	(3)	(4)
1	A	-	1.8	-	-
	B	**14.1**	70.5*	8.8	-
	C	-	2.4	0.4	-
2	A	6.7	64.8*	**10.6**	-
	B	1.5	3.9	9.5	-
3	A	7.5	-		-
	B	2.2	4.8	84.6*	-
4	A	4.4	**18.5**	3.5	-
	B	65.2*	2.6	5.7	-
5	A	**21.6**	8.4	3.1	-
	B	2.2	0.9	57.3*	-
6	A	5.3	3.5	5.3	-
	B	**11**	71.4*	2.6	-
7	A	9.7	9.3	1.8	-
	B	**21.6**	44.9*	2.2	-
	C	-	-	9.3	-
8	A	73.1*	5.7	8.4	-
	B	-	8	7	-
9	A	15	-	1.3	-
	B	6.6	**11**	62.1*	-
	C	-	3.1	.9	
10	A	**20.7**	3.5	3.5	-
	B	1.3	**12.8**	41.9*	-
	C	-	2.2	**14.1**	-
11	A	2.6	**10.1**	1.8	-
	B	0.9	-	0.9	4.8
	C	5.3	4	7	-
	D	0.9	0.4	55.9*	-
12	A	**19.4**	52.9*	5.3	-
	B	2.6	2.2	**16.3**	-
13	A	**12.8**	8.8	1.3	-
	B	2.2	1.3	2.2	-
	C	9.3	4.8	56.4*	-
14	A	-	1.3	-	1.3
	B	63*	6.2	5.3	**14.1**
	C	2.6	3.1	1.3	0.9
15	A	52.4*	**12.8**	5.3	4.8
	B	4	6.2	1.3	5.7
16	A	5.3	**11**	9.7	-
	B	7	9.3	-	-
	C	41*	7	3.5	-
17	A	53.3*	4.8	5.7	6.6
	B	4.4	**19.8**	4	-

Note: "-" represents less than 10%

Figures with "*" denote the percentage of students who provided correct answers

Figures in bold represent the percentage of students with alternative conceptions

Figure 5.1 presents the percentages of students who provided the correct responses to both tiers of the 17 items in the DOPT diagnostic instrument.

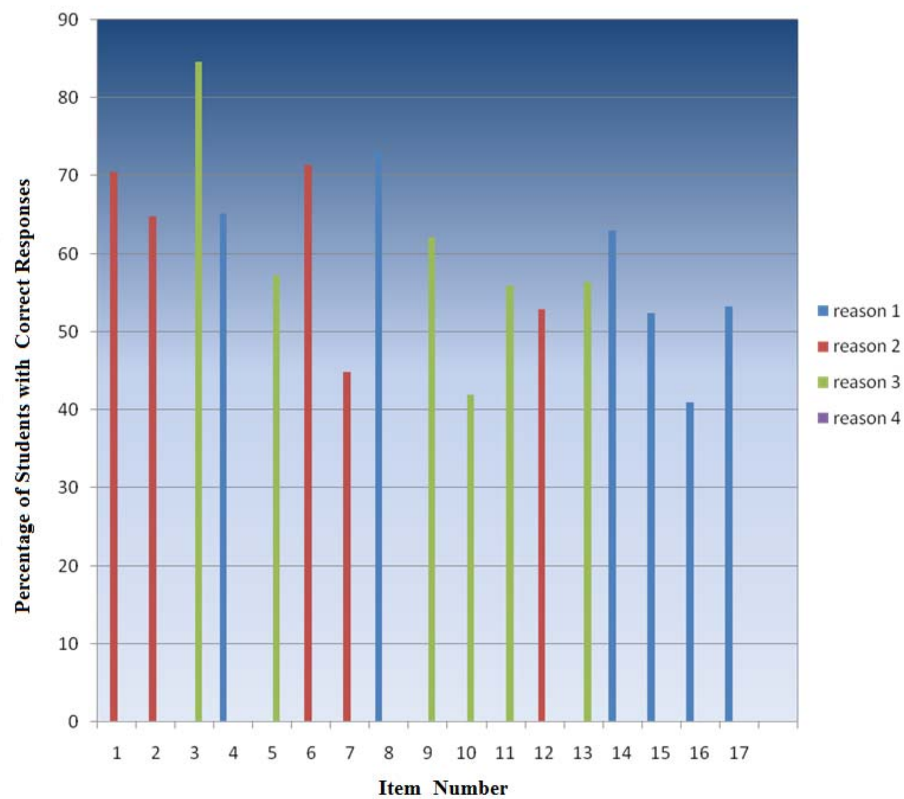


Figure 5.1. Percentages of students providing correct responses to items in DOPT diagnostic instrument (*n*=192)

As depicted in Table 5.2 and Figure 5.2, the percentage of students who were able to provide correct responses to the first tier of the items was over 50% in each of the 17 items. In the literature, a pass rate of over 75% is recommended by Gilbert (1977). Othman et al. (2008, p. 1539) used this benchmark of more than 75% of the students answering the item correctly to indicate satisfactory understanding of the concept (1977). Based on this criterion, the combinations of answers to the two tiers of the diagnostic test utilised in the study indicated a less than satisfactory understanding. In the particle theory part of the test (i.e., Items 9-17), none of the pre-service science teachers had a score above 62% on the correct answer combination.

Table 5.2

Percentages of Students Correctly Answering the First Tier Only and Both Tiers of the Items in DOPT Diagnostic Instrument (n=192)

Item*	Percentage of students correctly answering		Item	Percentage of students correctly answering	
	First tier	Both tiers		First tier	Both tiers
1	93.8	70.5	10	56.8	41.9
2	81.9	64.8	11	55.9	55.9
3	91.6	84.6	12	79.7	52.9
4	72.7	65.2	13	72.2	56.4
5	65.6	57.3	14	88.5	63
6	85.9	71.4	15	52.4	52.4
7	68.7	44.9	16	52.9	41
8	88.5	73.1	17	70.5	53.3
9	79.7	62.1			

**Items 1-8 are about diffusion and osmosis; Items 9-17 are about the particle theory*

5.3 Alternative Conceptions

The percentages of students holding various alternative conceptions are displayed in Figure 5.2.

The percentage of responses for each combination of content and reason choices was found in the results of the DOPT diagnostic test. For the purpose of this study, attention was only given to responses selected by more than 10% percent of the student group. Eighteen alternative conceptions were identified through an analysis of results of the DOPT diagnostic test as shown in Table 5.3. They are grouped and discussed in the following sections under two groups of headings: alternative conceptions relating to diffusion and osmosis; and alternative conceptions relating to particle theory (the particulate nature of matter).

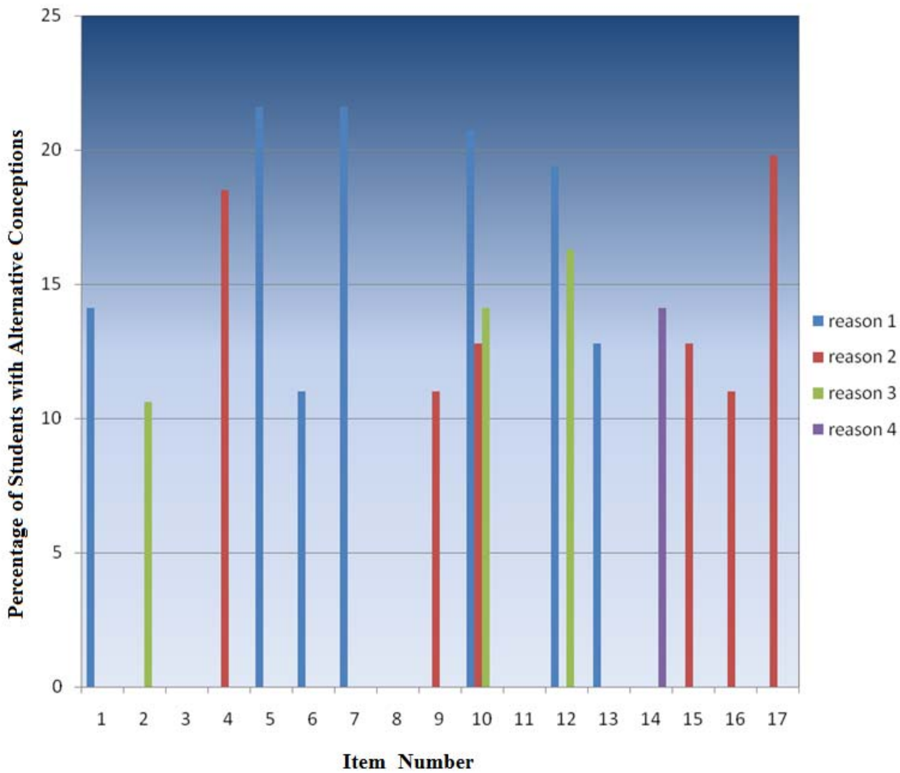


Figure 5.2. Percentages of students with alternative conceptions found by DOPT diagnostic instrument (*n*=192).

5.3.1 Alternative Conceptions Relating to Diffusion and Osmosis

5.3.1.1 Diffusion/concentration gradient and amount of solute (Items 2, 3 and 5)

In this study, pre-service teachers' ability to determine that diffusion is the best explanation of the random interaction of particles was limited (as measured by each of items 2, 3 and 5). For example, only 64.8% of them provided correct answers for Item 2, which is related to the process of diffusion of particles moving from a high concentration to a low concentration as the result of random interaction of particles.

Table 5.3

Alternative Conceptions Pre-service Teachers from the Results of the DOPT Diagnostic Test (n=192)

No.	Alternative conception	Item no.	Choice combination	% of pre-service teachers
1	Diffusion cannot occur without the presence of a semi-permeable membrane.	1	B1	14.1
2	The movement of particles between two solutions stops when the concentrations of the solutions become equal.	2	A3	10.6
3	When a small amount of soluble solid is added to water without stirring, the solution at the bottom will become more concentrated after some time because the denser solute particles sink to the bottom.	4	A2	18.5
4	After a substance has evenly diffused through water, the molecules of the substance stop moving.	5	A1	21.6
5	Diffusion of a substance in water occurs faster at a higher temperature because the substance is more stable at high temperatures.	6	B1	11.0
6	The vacuole of a plant cell placed in salt solution decreases in size because the salt absorbs water from the vacuole.	7	B1	21.6
7	The bubbles in boiling water contain the gases hydrogen and oxygen that are produced by the decomposition of water molecules.	9	A1	15.0
8	Heat energy is absorbed by boiling water and released as bubbles.	9	B2	11.0
9	The mass of a substance in the gaseous state is less than that of an equal amount of the same substance in the solid state.	10	A1	20.7
10	The mass of a given amount of a solid increases in the gaseous state because the particles have become more widely-spaced.	10	C3	14.1
11	Water vapour consists of hydrogen and oxygen molecules.	11	A2	10.1
12	When crystals of a soluble substance are added to water, the molecules of the solid absorb heat from the surroundings and melt before diffusing throughout the water.	12	A1	19.4
13	When crystals of a soluble substance are added to water, the solid dissolves only on stirring to break up the solid into smaller particles.	12	B3	16.3
14	A single atom of an element exhibits the same properties as the element itself.	13	A1	12.8
15	States other than solids do not have strong attractive forces holding the particles together.	14	B4	14.1
16	The molecules of a dense gas will sink rapidly to the bottom of the container in a partial vacuum because the particles are heavy.	15	A2	12.8
17	When a gas is compressed the volume and mass of the gas decrease because the molecules of the gas become compressed.	16	A2	11.0
18	A liquid that is miscible with water but denser than water will not diffuse uniformly because the heavier particles sink to the bottom.	17	B2	19.8

The most common alternative response for Item 2 may have resulted from a misunderstanding about the terminology used. For example, many of the pre-service teachers selected “particles generally move from high to low concentrations because they tend to move until the two areas are isotonic and then stop moving altogether”. In this case, pre-service teachers might have memorised the prefix *iso*, to mean *the same thing* and thus interpreted this item to mean that particles would continue to move until they are of the same concentration throughout. Both tiers of Item 3 were answered correctly by 84.6% of the pre-service teachers with no alternative conceptions. However, for Item 5, 21.6% of them made their selections that indicated they believed that “After a substance has evenly diffused through water, the molecules of the substance stop moving”.

5.3.1.2 Differentiating between osmosis and diffusion (Items 1, 4)

The pre-service teachers’ ability to completely understand the process of diffusion was assessed through two items. In Item 1, a single drop of blue dye was placed in a container of clean water. Over time the dye became evenly distributed throughout the water. In total, 70.5% of the pre-service teachers selected the correct answer combination, that is, the process responsible for the dye becoming evenly distributed throughout the water is the movement of particles between regions of different concentrations. The most common alternative conception for the phenomenon was “diffusion” with 14.1% of respondents suggesting “the lack of a membrane means that osmosis and diffusion cannot occur”.

In Item 4, a small amount of sugar was added to a container of water that was allowed to stand for a one to two hour period of time without stirring. The correct response combination was: “the sugar molecules will be evenly distributed throughout the container because there is movement of particles from a high to a low concentration”. In this case, the most common alternative conception, held by 18.5% of respondents, was: “the sugar molecules will be more concentrated on the bottom of the container” because “the sugar is heavier than water and will sink”.

5.3.1.3 Process of osmosis (Item 7)

The process of osmosis was evaluated utilising Item 7, which assessed the process of osmosis in a plant cell. It showed a picture of a plant cell normally living in fresh water that was placed in 25% saltwater. Students were asked to determine what would happen to the size of the central vacuole of the cell as a result of the immersion in saline. The correct response was: “the central vacuole would decrease in size because the water will move from the vacuole to the salt water solution”. Only 44% of the pre-service teachers gave the correct combination for the answer to Item 7. With this item the most common alternative conception was that, “salt absorbs water from the vacuole” as indicated by 21.6% of respondents.

5.3.1.4 Semi-permeable membranes (Item 8)

Item 8 measured the ability of pre-service teachers to understand the structure of a cell membrane with 73.1% choosing the correct answer combination which stated “all cell membranes are semi-permeable” because “they allow some substances to pass”. No alternative conceptions were identified.

5.3.1.5 Effect of temperature on solubility (Item 6)

For this concept, assessment was by Item 6 which considered the effects of the temperature on molecules. The majority of pre-service teachers (71.4%) selected the correct answer combination that “if a drop of green dye is added to beakers with equal amounts of clear water at two different temperatures (beaker 1: 25°C and beaker 2: 35°C); beaker 2 becomes light green first because the dye molecules move much faster at a higher temperature”. No alternative conceptions were identified.

5.3.2 Alternative Conceptions Relating to Particle Theory (the Particulate Nature of Matter)

5.3.2.1 Change of state (Items 9 and 11)

Items 9 and 11 revealed alternative conceptions regarding changes of state: 15% of respondents believed that “the bubbles in boiling water contain the gases hydrogen and oxygen that are produced by the decomposition of water molecules” and 11% held the belief that “heat energy is absorbed by boiling water and released as bubbles”. For the case of evaporation in Item 11, 10.7% of respondents believed that oxygen and hydrogen molecules are produced.

5.3.2.2 Dissolving (dissolution) (Item 12)

A number of alternative conceptions were identified from the pre-service teachers' answers to Item 12 relating to the dissolving process. This result indicated that the pre-service teachers had not clearly understood this concept. Nine pre-service teachers held the conception that when sugar dissolves, "it melts forming a liquid that mixes with water" (19.4% of respondents). Another alternative conception identified among pre-service teachers was that "sugar only dissolves when stirred as stirring causes the crystals to break into smaller particles that will spread in the water and can no longer be seen" (16.3% of respondents).

5.3.2.3 Macroscopic and sub-microscopic properties (Item 13)

The most common alternative conception that was identified regarding Item 13 was that "a single atom of an element exhibits the same properties as the element itself when in fact the properties are determined by the interaction between individual particles of the element" (12.8% of respondents).

5.3.2.4 Particle arrangement in solids, liquids and gases (Item 14 and 16)

The pre-service teachers' overall performance in the Items 14 and 16 indicated that they had not yet acquired an adequately sound understanding of the arrangement of particles. In the case of Item 14, the most common alternative conception identified was that "states other than solids that do not have strong attractive forces holding the particles together" (held by 14.1% of respondents). For Item 16 the most common alternative conception was, "when a gas is compressed the volume and mass of the gas decreases because the molecules of the gas become compressed" (11% of respondents).

5.3.2.5 Diffusion in gases and liquids (Item 15)

This concept was evaluated by Item 15 which assessed the diffusion in gases and liquids. Only 52.4% of the respondents chose the correct combination. The most common alternative conception was that the molecules of a dense gas will sink rapidly to the bottom of the container in a partial vacuum because the particles are heavy.

5.4 Correlation of Diffusion and Osmosis and the Particulate Nature of Matter

The results of associations between diffusion and osmosis and the particulate nature of matter are displayed in Table 5.4. In interpreting the value of the coefficient of correlation, the following set of categories was used:

0.75 – 0.99	high correlation
0.51 – 0.74	moderately high correlation
0.31 – 0.50	moderately low correlation
0.01 – 0.30	low correlation
0.00	no correlation

The results of the Pearson Product-Moment correlations shown in Table 5.4 indicate that the scores of the items on diffusion and osmosis and the scores of the items on the particulate nature of matter are highly positively correlated. In this case it means that when scores in diffusion and osmosis are increased or decreased, the scores in the Particulate Nature of Matter are also increased or decreased.

Table 5.4

Correlation of Scores of Items on Diffusion and Osmosis and Scores of Items on Particle Theory (Particulate Nature of Matter) in DOPT Diagnostic Instrument (n=192)

		Total DO	Total PT	Total Inst
Total DO*	Pearson Correlation	1	.417**	.853**
Total PT*	Pearson Correlation		1	.830**
Total lnst*	Pearson Correlation			1

*DO = Diffusion and Osmosis; PT = Particulate Theory; Inst =Instrument

** Correlation is significant at the 0.01 level (2-tailed)

Cronbach's alpha coefficient is a commonly used measure of reliability (Adams & Wieman, 2010). The author, Cronbach, however, warned against depending on these measures too heavily. He commented: "Coefficients are crude devices that do not bring to the surface many subtleties implied by various components" (Cronbach as cited in Adams & Wieman, 2010, p. 16). The internal consistency of the 17 items was determined resulting in a Cronbach's alpha coefficient of 0.54. This result, however, fell short of Nunnally's (1978) recommended reliability coefficient of 0.60 or greater.

The values of the Difficulty Index (P) and the Discrimination Index (D) (see Section 4.4) for the 18 items in the main study are shown in Table 5.5. It can be seen that, with Difficulty Indices from 0.40 to 0.84, the items in this study provided a wide range of difficulties. For example, while an index of 0.7 may indicate an excessive degree of difficulty for an achievement test, it is the wide range that is appropriate to determine how many of the pre-service teachers have different kinds of alternative conceptions (Ary, Jacons, & Razarieh, 2009).

As discussed earlier, a value of 0.2 was established as the minimum without the need for further revision of the test items (Odom & Barrow, 1995). It should be noted that the instrument was not intended to have a normative function; rather an intended function was to ascertain the conceptual level at which pre-service teachers are working. A summary of Difficulty Index and Discrimination Index for the 17 items in the main study is presented in Table 5.6. The Difficulty Index is categorised into three groups 0.2 to 0.5, 0.5 to 0.7, and greater than 0.7.

Table 5.5

Difficulty Index (P) and Discrimination Index (D) for 17 Items in DOPT Diagnostic Instrument (n=192)

Item no.	Difficulty index	Discrimination index
1	0.69	0.30
2	0.64	0.21
3	0.84	0.31
4	0.65	0.24
5	0.59	0.50
6	0.71	0.39
7	0.44	0.47
8	0.73	0.73
9	0.62	0.36
10	0.41	0.39
11	0.55	0.29
12	0.52	0.24
13	0.56	0.40
14	0.62	0.36
15	0.52	0.13
16	0.40	0.49
17	0.53	0.49
Mean	0.59	0.37

Table 5.6

Summary of Difficulty and Discrimination Indexes for 17 Items (n=192)

Difficulty Index P	Item	Discrimination Index D	Item
0.2≤ P < 0.5	7, 10, 16	0.1 ≤ D < 0.3	2,4,11,12,15
0.5≤ P < 0.7	1,2,4,5,9,11,12,13,14,15,17	0.3 ≤ D < 0.5	1,3,5,6,7,9,10,13,14,16,17
P > 0.7	3,6,8	D > 0.5	8

5.5 Reliability and Validity of the Test of Science-Related Attitudes (TOSRA)

The TOSRA questionnaire was administered to a sample of 217 pre-service teachers who had responded to the two-tier diagnostic instrument. The measurement to validate the questionnaire was the Cronbach alpha coefficient (Cronbach, 1951) that was used to assess the internal consistency of the scales and to obtain the evidence to support the instrument's construct validation. Internal consistency was determined on the 30 items in the TOSRA questionnaire representing pre-service teachers' views of science and was found to be 0.65, which compares well with values from other studies. For instance, the value of internal consistency reliability of the TOSRA reported by Fraser (1977b) was in the range of 0.69 to 0.84.

These results are shown below in Table 5.7. As can be seen, an acceptable level of reliability was shown with the exception of the Adoption of Scientific Attitudes scale, which had an alpha reliability of 0.43, which is at the lower end of the acceptable limits (Hassn, 2004). Therefore, it is suggested that the results from this scale need to be treated with some caution. The results of total associations between the means of the three scales are presented in Table 5.8.

Table 5.7

Scale Means, Standard Deviations, Internal Consistency (Cronbach Alpha Coefficient) and Discriminant Validity (Mean Correlation with Other Scales) for the TOSRA (n=192)

TOSRA Scales	Number Correlation of items	Scale Mean	Standard Deviation	Alpha Reliability	Mean with other scales
Adoption of Scientific Attitudes	10	3.74	.32	.43	.20
Enjoyment of Science Lessons	10	3.93	44	.82	.36
Attitude to Scientific Inquiry	10	3.78	.47	.70	.51

Table 5.8

Associations between the Means of Adoption of Scientific Attitudes (Att), Enjoyment of Science Lessons (Enj) and Attitude to Scientific Inquiry (Inq) in Determining the Attitude of Students Towards Science (n=192)

		Mean Inq	Mean Att	Mean Enj
Mean Inq	Pearson Correlation	1	.470**	.488**
Mean Att	Pearson Correlation		1	.443**
Mean Enj	Pearson Correlation			1

** Correlation is significant at the 0.01 (2-tailed) level

The results of the Pearson Product Moment Correlation indicate that the scores on the Attitude to Scientific Inquiry are correlated to the means of Adoption of Scientific Attitude and the Enjoyment of Science Lessons and that these relationships are significant at the 0.01 (2-tailed) level.

5.6 Mean and Standard Deviations

Central tendency is measured by the mean and the standard deviation in conventional educational research (Wiersma, 1986). The sum of the scores divided by the number of scores gives the mean of the data while the standard deviation is determined by comparing the average distance each score is from the arithmetic average. Both the mean and standard deviation are viewed often in light of the data's discriminant validity (Munro, 2005). The discriminant validity of the instrument was measured for using each of a scale's mean correlation with other scales. In this case the mean correlation ranges from 0.20 to 0.50 (as shown in Table 5.8) using the individual as the unit of analysis. This range indicates that the items used in the instrument correlate more greatly with items in the same scale than with the items in other scales (Munro, 2005). Consequently, the instrument has the satisfactory discriminant validity and each of the scales has measures that are generally distinct from each other, although this has somewhat overlapping attitudes.

5.7 Summary

The evidence from the diagnostic tests demonstrated that many of the pre-service science teachers faced conceptual difficulties in the complete understanding of diffusion, osmosis and the particulate nature of matter. The results from the study indicated that the instrument was able to diagnose the extent of pre-service teachers' understanding of the two topics. The results suggested that pre-service teachers were often able to select the correct content option; however, they struggled to select the correct justification option. The outcome of this study was that more of pre-service teachers' answers were correct on the first tier alone, that is, when only the answer to the first tier of the items is considered and not both tiers of the items. The findings based on the responses of the pre-service teachers to the test items suggested that it is possible to determine the statistically significant correlations between the pre-service teachers' responses and their understanding of diffusion, osmosis and the particulate nature of matter.

In addition, the statistical analysis of the data shows that the pre-service science teachers' in Saudi Arabia will continue to have alternative conceptions in relation to these concepts, on par with other international pre-service science teachers. The diagnostic test has identified the alternative conceptions which help demonstrate the ways in which evaluation of pre-service teachers' understanding is relevant to improving instruction. By identifying alternative conceptions, teachers gain insight into the understandings of their students and are then able to plan instruction which better guides learners towards the correct answers.

Another one of the objectives of this investigation was to validate the TOSRA and to show how the TOSRA, with some modifications, is reliable and valid for studying Saudi Arabian pre-service teachers. It has demonstrated with pre-service science teachers of Saudi Arabia that an instrument to assess the factors affecting the understanding science could be utilised to improve the understanding of science. It has been further demonstrated that this research possesses a satisfactory degree of validity and reliability as supported by various statistical tests. Specifically, the reliability estimates indicate that the two out of the three scales of the TOSRA, Enjoyment of science lessons and Attitude to scientific inquiry, are valid measures for investigating factors that might be associated with pre-service science teachers' understanding of science, particularly of diffusion, osmosis and the particulate nature of the matter. Despite the pre-service teachers' overall perceptions of science being positive, there remains room for improvement especially in the adoption of more positive attitudes.

CHAPTER SIX

RESULTS FOM INTERVIEWS

6.1 Overview of the Chapter

This chapter provides a summary of the interview responses made by a group of ten pre-service science teachers in Saudi Arabian teachers' colleges. The interview questions were semi-structured with the goal of gathering data about the reasons for pre-service teachers' choices in the DOPT diagnostic instrument. Particular attention was paid to the justifications that pre-service teachers gave for incorrect answers. Student teachers' answers, translated from Arabic to English, are quoted in this section with as much depth and completeness as possible in order to highlight the position of the pre-service teachers regarding the subject matter questions. In other words, how the mind processes that support popular scientific misconceptions were studied through the interview method and results of the interviews. In addition, the limitations of the interview transcriptions and processes are discussed. Finally, a summary of the chapter is provided.

6.1.1 Results (Summary of Responses)

The first part of the interview concerned questions which were related to the general educational environment and the level of satisfaction that the pre-service teachers held regarding their participation in the study.

The second part of the interviews concerned the diagnostic test, questioning the student teachers about their answers and justifications on a range of questions related to diffusion and osmosis and the particulate theory of matter. The questions asked in this part of the interview focused on the common wrong answers that student teachers thought to be correct and on the reasons why their misconceptions were so common.

6.1.2 Classroom – Laboratory Blend

Nine out of the ten pre-service teachers indicated that they felt the theory which they studied in the classroom relating to scientific concepts suitably matched and supported the work that they completed in the laboratories. The exact wording, translated from Arabic, of this question used phrases such as “(Does) the theoretical framework for learning about diffusion and osmosis and the particulate nature of matter complement the actual practice in the laboratory?” And the common student teacher’s response was “yes”. One student teacher was not sure about his response and after some contemplation commented that he had been absent for some time from the class and therefore he struggled with the concepts from the class and the laboratory work did not help his understanding. He said the following:

> *I have missed many classes this term because of some family and health problems which were out of my control; also I have found the course confusing so I can’t say that the class work and laboratory work matched because I missed too much. (ST1, interview)*

6.1.3 Laboratory Confidence for New Teachers

All ten pre-service science teachers stated that they would not feel confident in conducting biology experiments for the benefit of their future biology students. This finding is of concern because for a college trained science teacher, it would be expected that the graduate could enhance the learning experiences of primary and secondary aged school students through practical experiments. The preparation program offered at the teachers’ colleges in which the study was conducted had the facilities for the student teachers to conduct laboratory experiments. However, it is assumed from the comprehensive lack of confidence that pre-service teachers did not take advantage of the opportunity to learn by themselves with the laboratory equipment. Consequently, teacher trainers should re-consider the role of laboratory activities in biology teachers’ preparation because, based on this small sample of pre-service biology teachers, all interviewees had some apprehension about their ability to conduct laboratory experiments in biology:

> *We did many things ok once but that’s not really enough for us to build the confidence that we need. (ST2, interview)*

Asked how the student teachers would overcome the issue of not being able to conduct laboratory experiments in biology for the benefit of their students’ learning, the sample of interviewees were divided in their responses. Six of the student teachers responded that they would seek help from a more qualified and experienced science teacher while the other four in the sample said that they would seek the help of laboratory technicians. However, there are other comments.

It is better for me to see what the teachers at the school do. (ST3, interview)

Different schools have different booking systems with laboratory equipment. (ST4, interview)

Science teachers have a more difficult job than the other teachers because we have to set up laboratory experiences for the students as well. The other subjects don't really do this. (ST8, interview)

The positive aspect of these responses was that at least the student teachers were confident in solving the problem of their lack of confidence through seeking help. However, again, it seems that their confidence to use the laboratory should be a stronger and more empowering part of pre-service teacher preparation. From the above student teachers' responses, it seems that there needs to be more focus on developing confidence and consistency in pre-service science teachers.

6.1.4 Student Teachers' Satisfaction with Teacher Training Staff

The student teachers were not, on the whole, satisfied with their instructors in these Saudi teaching colleges. Six student teachers in the sample stated "no" in response to the question "Are you satisfied with the performance of your lecturers?"

I think because we are training to be teachers we should have the best teachers to show us what to do. (ST4, interview)
The teachers are good by themselves but are not good at working with the course curriculum in a team. (ST5, interview)

The fact that 60% of the student teachers in the sample of this study were dissatisfied with their teaching staff is a significant sign that there are issues within the current teachers' college system. It was important to delve into this area to better understand the reasons for this feeling of discontent with their lecturers. A number of the dissatisfied student teachers commented that, for both biology and chemistry classes, the problem was that often the lecturer taking the theory component of the course was a different person from the lecturer or technician holding the laboratory sessions. While this was generally not a problem, the student teachers highlighted that the two dimensions—the theory and practical—of the subjects were not closely matched. For example, sometimes student teachers would do laboratory experiments without having done the theory beforehand as one of them said:

> *Sometimes the laboratory handouts and exercises asked us to complete questions which needed the theoretical background. (ST6, interview)*

Therefore, they felt lost. In other cases, the theory was done three or four weeks before the laboratory sessions so the subject matter had faded in the student teachers' minds when they did the laboratory work.

Another one of the problems which caused dissatisfaction in the teacher training for teaching biology and chemistry subjects was the assessment of laboratory tasks. Students commented in the interviews that the examinations required the student teachers to memorise steps in particular laboratory experiments that were conducted throughout the semester. Some student teachers mentioned that this approach was not beneficial as student teachers did not comprehend the experiments and that they had only rote learned the steps. It appeared that the student teachers were seeking an alternative format for the assessment of the practical component of the course that was both hands-on and required thinking. Nonetheless, it must be mentioned that four out of the ten student teachers did comment that they were satisfied with their teachers. However, this is a low proportion by any measure. One of them said:

> *For me, the classes and lab work is fine but I know that many of my peers think that the course is unorganized. (ST7, interview)*

6.1.5 Chemistry versus Biology Balance

While student teachers were not satisfied with the teaching staff, surprisingly, all ten pre-service teacher respondents agreed that the current curriculum was well-balanced in terms of biology theory and laboratory classes and the same for chemistry. It is unclear whether all student teachers perceived that an equal number of hours per week was a sufficient measure of this balance, however, some of the student teachers' responses suggested this:

> *We have four hours of biology per week and four hours of chemistry per week so it is even (ST7, interview)*

> *Both chemistry and biology are difficult but I don't think one is harder than the other. (ST8, interview)*

6.1.6 Student Teacher Preference: Theory or Practical Classes

Seven of the ten pre-service teacher respondents commented that they preferred the laboratory classes to the theory classes. In fact, a range of different justifications were given for this choice of practical over theory; however, the main themes were the fun of being hands-on and the fact that the theory classes were inactive:

> *The lab technicians here are really friendly so sometimes they let us conduct our own little experiments when we have finished the main tasks (ST5, interview)*

> *I think I'm like most student teachers here; I can do the practical tasks easily (ST3, interview)*

Some of respondents with this opinion of preferring practical classes commented that they felt they learned more in these classes:

> *I can't remember what is happening in the theory classes, but the practical lessons are easier for me (ST9, interview)*

However, three student teachers out of the ten said that they preferred the theory classes. All three commented that it was easier to grasp the core content through attending lectures:

"I only remember the subject matter when I study it by reading it or writing it (ST10, interview)

The good thing about the lectures in class is that the teachers tell us which parts of the textbook we must know and which parts are not important (ST3, interview)

These answers caused some concern that the teachers may be teaching to the test. In other words, instead of making sure the students have a good understanding of the theories, the teachers are more concerned with the students passing the test. The following comment highlighted this:

It looks good for us and the teacher when we get a high mark (ST5, interview)

6.2 The Diagnostic Test

To better characterize the reasons why students were led to incorrect answers, the researcher selected, sought consent and interviewed the ten students who had inaccurate responses. As in the first part, the interviews were tape-recorded and transcribed in order to establish a framework for analyzing understanding of osmosis, diffusion, and the particulate nature of matter. Most of the pre-service science teachers interviewed had almost the same perceptions about the given questions. For each of the comments included below, Student Teacher 1 or Student Teacher 2 refers to a different student teacher. If student teachers were found to give an incorrect answer the researcher attempted to investigate the student teacher's wrong conception and try to determine the reasons which caused the error. Most important are that the possible implications for teaching biology and chemistry are considered and that these findings will be further described in the discussion sections.

In total, seven items are reported. Each set of results has the question as it was asked to the student teachers. The results include the student teachers' justifications of their answer and the researcher's comments on the nature of the wrong conception and some preliminary implications for teaching. Only student teacher responses in Item 5 were for items where the responses showed significant inaccuracy.

6.2.1 Comments (Item 2 on DOPT)

For this item, the comments of one student teacher who provided the answer A3 is as follows:

Researcher: During the process of diffusion, particles will generally move from:

a. high to low concentrations
b. low to high concentrations

The reason for my answer is because:
1. There are too many particles crowded into one area; therefore, they move to an area; with more room.
2. Particles in areas of greater concentration are more likely to bounce towards other areas.
3. The particles tend to move until the two areas are isotonic, and then the particles stop moving.

(Correct response pair in italics)

The answer provided by Student Teacher 1 is A3

Student Teacher 1: Particles will generally move from (a) high to low concentrations because (3) the particles tend to move until two areas are isotonic, and then the particles stop moving.

Researcher: Why do you think that particles tend to move until the two areas are isotonic then the particles stop moving?

Student Teacher 1: Because according to my teacher the particles would continue to move until they are "the same" concentration throughout.

Researcher's comments: This student teacher may have memorized the meaning of isotonic, which mean 'the same' and interpreted this item to mean that particles would continue to move until they are the same concentration throughout. The misunderstanding concerns the movement of the particles. The theory holds that particles are in constant motion, and that they randomly move from higher to lower concentrations. There is no feature which makes the particles stop moving once two solutions are equal.

The implications for teaching here are that there needs to be more stress on the fact that particles are always in motion. The same student teacher was asked directly if he understood the concept. Therefore, this is the same item but a different question.

Researcher: Do you understand the concept of diffusion?

Student Teacher 1: Not really, my teacher didn't explain that well.

Researcher's comments: Diffusion is the tendency of the material that forms a fluid or gas to move down a concentration gradient: from regions of higher concentration to lower concentration.

For teachers it appears important that they stress that the particles prefer to be in freer spaces, that is, where there are less collisions.

6.2.2 Comments (Item 7 on DOPT)

For this item, the results from two student teachers are included.

Researcher: Figure 4 is a picture of a plant cell that lives in freshwater. If this cell were placed in a beaker of 25% saltwater solution, the central vacuole would:

a. increase in size

b. decrease in size

c. remain the same size

The reason for my answer is because:

1. Salt absorbs the water from the central vacuole.
2. *Water will move from the vacuole to the saltwater solution.*
3. Salt solution outside the cell cannot affect the vacuole inside the cell.

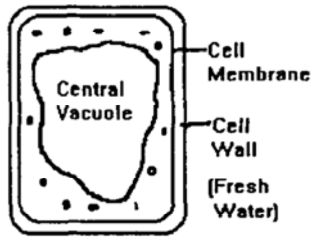


Figure A4.

(Correct response pair in italics)

The answer provided by Student Teacher 2 is A1.

Student Teacher 2: If the cell were placed in a beaker of 25% saltwater solution, the central vacuole would (A) increase in size for (1) the reason the salt absorbs water from the central vacuole.

Researcher: Why do you say that the salt absorbs water from the central vacuole?

Student Teacher 2: Because like a sponge, a paper towel absorbs water.
Researcher's comments: The meaning of absorb may be different in a scientific context than in a non-scientific one. Common experiences in a non-scientific context are that like cotton absorbs water. If 'absorb' is viewed as the taking away of water, then the student teacher may have believed that the saltwater solution absorbed the freshwater. Student Teacher 2's results are common misconceptions according to researchers (Nakhleh, 1994; Treagust, & Chittleborough, 2001). Therefore, it is important that this concept is taught in clear ways to student teachers. Students need to be taught the meanings of words. There are many words which are used loosely in literature; however, in science they have precise meanings such as power and force.

The answer provided by Student Teacher 3 is A3

Researcher: Do molecules normally tend to diffuse across the membrane from a less concentrated to a more concentrated solution or from a more concentrated to a less concentrated one?

Student Teacher 3: From lower to higher

Researcher: Which has higher concentration? The central vacuole or saltwater solution?

Student Teacher 3: Saltwater

Researcher: So do molecules diffuse from outside or inside the central vacuole?

Student 3: Inside

Researcher: Then the central vacuole will decrease in size, is it right?

Student 3: Yes

Researcher: But your answer to this question is different.

Student 3: Because I think 25% is not enough to make molecules diffuse from lower to higher concentration.

Researcher: If I gave this question without mentioning '25%' what will be your answer?

Student Teacher 3: B2

Researcher's comments: The student teacher seems to be confused by the addition of the 25%. Therefore, 25% should be omitted from this question in future studies.

6.2.3 Comments (Item 4 on DOPT)

Researcher: 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

The reason for my answer is because:

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

2. the sugar is heavier than water and will sink

3. there will be more time for settling

(Correct response pair in italics)

The answer provided by student teacher 4 is A2.

Student Teacher 4: It will be more concentrated at the bottom of the container because the sugar is heavier than water and will sink.

Researcher: Why will the sugar sink?

Student Teacher 4: The heavier one will sink.

Researcher's comments: One interpretation of these results is that student teachers integrated gravity concepts into solution chemistry. Students can see sugar granules sink to the bottom of the container. If student teachers ignored the condition (that the sugar was allowed to set for a very long period of time), their response would describe what happens when sugar granules are first placed in the container. It appears that some of the aspects of this experiment are outside of the school experience of the student teachers.

6.2.4 Comments (Item 1 on DOPT)

Researcher: Suppose you add a drop of blue dye to a container of 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.

The reason for my answer is because

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

2. If the dye molecules stopped, they would settle to the bottom of the container.
3. Molecules are always moving.

(Correct response pair in italics)

The answer provided by Student Teacher 5 is A2

Student Teacher 5: Molecules of dye will have stopped moving then would settle to the bottom of the container.

Researcher: Why will the molecules settle in the bottom of the container?

Student Teacher 5: Because the container was not moved for some time, so the molecules will sink to the bottom.

Researcher's comments: Here it appears there is confusion between particles settling to the bottom of a container in the same way that dust would settle at the bottom of a tank of water and particles which are even distributed throughout the solution. Teachers need to highlight the difference in the relative size of the items in discussion highlighting the relative difference between dust specks and particles.

6.2.5 Comments (Item 8 on DOPT)

Researcher: All cell membranes are:
a. semi-permeable
b. permeable

The reason for my answer is because:
1. They allow some substance to pass through
2. The membrane requires nutrients to live
3. They allow all nutrients to pass

(Correct response pair in italics)

The answer provided by Student Teacher 6 is A3**.**

Student Teacher 6: All cell membranes are semi-permeable because they allow some substances to enter, but they prevent any substances from leaving.

Researcher: What enables the cell membrane to allow substances to enter?

Student Teacher 6: Because most of the cell membrane is a selectively permeable barrier: some materials cross freely and others cross only at certain times. (By this it appears that the student teacher is referring to the cellular gateways, the globular proteins, of the membrane which can open and close.)

6.2.6 Comments (Item 9 on DOPT)

Researcher: Assuming a beaker of pure water has been boiling for 30 minutes. What is/are in the bubbles in the boiling water?

a. oxygen gas and hydrogen gas
b. water vapor (water in gaseous state)

Reason
1. The hydrogen and oxygen atoms in water molecules break away from each other to form gases.
2. Heat energy is absorbed by the water and released as bubbles.
3. The forces between the water molecules are overcome, and the water molecules break free from the liquid steam.

(Correct response pair in italics)

The answer provided by Student Teacher 7 is A1

Student Teacher 7: Oxygen and hydrogen gases are present in the bubbles of boiling water.

Researcher: Why?

Student Teacher 7: The water molecules break up and form gases like oxygen and hydrogen.

Researcher: How do the molecules break away?
Student Teacher 7: Because of the heat.

Researcher's comments: Student Teacher 7's comments show that he may believe that water is only a liquid and that when it turns into a gas it becomes either Oxygen or Hydrogen or both Oxygen or Hydrogen. This is a common misconception that student teachers hold. The implications for teaching this basic chemistry are that students must be informed that although ice, water, and steam have different names in scientific terms they are actually all water. Teachers could spend time highlighting the different properties of oxygen gas, hydrogen gas, and water in gaseous form.

6.2.7 Comments (Item 12 on DOPT)

Researcher: Crystals of sugar are placed in a beaker of water. If the mixture is left to stand long enough, the sugar crystals eventually can no longer be seen, and the water will taste sweet. True or False?
Students Teacher 8: False

Researcher: Do you think that would be the correct answer?

Student Teacher 8: Yes

Researcher: Can you explain?

Student Teacher 8: As long as the sugar is not stirred the sugar will not be mixed up in the water.

Researcher: So you believe that if there are no actions like stirring the solution, the sugar will not dissolve in the water?

Student Teacher 8: Yes

Researcher's comments: An indication that the student teacher has not clearly understood the concept of dissolving is that he reported on the idea that a substance like sugar will not spread and mix up in water if not stirred.
(Student Teacher 10 was asked the same question)

Researcher: Crystals of sugar are placed in a beaker of water. If the mixture is left to stand long enough, the sugar crystals eventually can no longer be seen, and the water will taste sweet. True or False?

Students Teacher 10: True, only if the water is heated first.

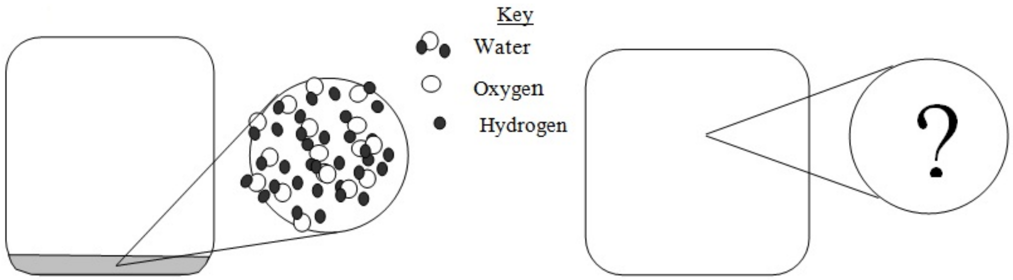
Researcher: Does the water need to be heated to dissolve the sugar? What about non-heated water?

Student Teacher 10: Then it can't and we can see the sugar.

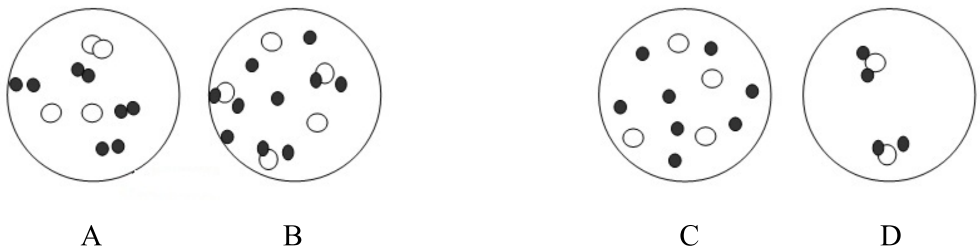
Researcher's comments: In the case of student 10, he understands that heat is involved in the process; however, his understanding exaggerates the importance of heat. Increasing the temperature increases the amount of solute that can dissolve. In the case of sugar at room temperature, some solute can dissolve without heat and stirring. The implications for teaching are that students at this level need a much stronger understanding of the factors which influence dissolving. The Royal Society of Chemistry (2010) states that students and teachers of science need a stronger understanding of the concepts of sieving, filtering, and evaporating and that these concepts can be taught through concept cartoons.

6.2.8 Comments (Item 11 on DOPT)

Researcher: The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.



What would the magnified view show after the water evaporates?



Reason:

1. Water molecules have escaped into the air.
2. Water molecules have decomposed into oxygen and hydrogen gas.
3. *Water molecules have spread further apart.*
4. A mixture of water molecules, oxygen atoms and hydrogen atoms are produced

(Correct response pair in italics)

Student Teacher 9: I choose options C and 1 for my reason, if water will evaporate the water molecules will escape into the air.

Researcher: How do the molecules escape into the air?

Students Teacher 9: Because as my teacher told me before if water is heated it will evaporate.

Researcher's comments: These students provided an explanation by description. Students using such phenomenon-based reasoning do not distinguish between a description and an explanation. The need for students to develop satisfactory relational explanations for scientific concepts was stressed by Moore and Harrison (2002). The pair's study found that while most students can describe scientific situations, teachers fail to ensure that their students can explain the occurrences.

The results of the interviews with pre-service science teachers revealed that their misconceptions were mainly dependent on instructional strategies of biology courses which was based on memorization of concepts. Due to the time limitation of their lessons, students are not able to achieve a complete understanding of the concepts and lack adequate laboratory experiences which are necessary for them to be able to relate their knowledge to real-life situations.

6.3 Limitations

It is important to list the limitations of the above results of the interviews. First of all, ten student teachers were a very small sample. Therefore, the results were only a small indication of the conceptions and beliefs of the total population of pre-service teachers.

Regarding the first part of the interview, it must be mentioned that the student teachers might have felt some restriction to their comments based on cultural influences. Education in Saudi Arabia is still in its developmental stages and it is often reported that students, even student-teachers, do not like to speak out of place, or provide negative feedback about their teachers. For this reason, it is expected that many of the students would have held back their true feelings about their teacher training, especially their lecturers.

The translation of words impacts on the validity of the answers as there is a large difference between the two languages used in this study, Arabic and English; and therefore exact word-for-word translation is difficult. Single words, in terms of semantics, can very rarely be translated satisfactorily. Nonetheless, to limit the bias in translation, the study involved translations, back translation and verifications of the inquiry discourse.

Finally, something that was unforeseen was that the principals in the different settings placed strict restriction on the time that the researcher could interview students. Originally, much more in detail and lengthy interviews were planned. However, due to these imposed time restrictions, the researcher had to limit the scope of the interviews; otherwise much more data could have been collected and reported on.

6.4 Summary of the Chapter

The results of the interviews were presented in two parts. The first part is the student teachers' opinions about their teacher training on the whole. The second part is the results of the diagnostic tests concerning diffusion, osmosis and the particulate nature of matter. For the first part, regarding the classroom and laboratory blend, 90% of the interviewees commented that they were satisfied with the division of academic and practical focus. One of the areas where the interviewees were not so sure was their level of confidence conducting laboratory experiments as first-year student teachers. In fact, 100% of these pre-service teachers said that they would not be confident, and 60% of this group said that they would need to rely on more experienced teachers and 40% would rely on laboratory technicians.

Something which is of concern is that 60% of the interviewees said that they were not satisfied with instruction they received, the main reason being given was the disorganization of the lessons. Having said this, all of the interviewees said that they were happy with the division of work between biology and chemistry. They on the whole enjoyed the practical classes (70%) more than the theory classes (30%).

Regarding the second part of the findings, there were at least one or two student teachers who selected incorrect answers for different items. When questioned were asked about their responses, the student teachers often linked their misconceptions with their teachers' instruction in teachers' colleges. This again reinforces the need for these teachers to review some of their teaching tasks relating to scientific concepts.

CHAPTER SEVEN

DISCUSSION

7.1 Introduction

This chapter discusses the data gathered to answer the research questions. Data collected using the diagnostic instruments, TOSRA and the student interviews are included. This chapter provides the outcome of the triangulation that is the cross-checking of assumptions through using two or more methods in this study: diagnostic test data, interview data and TOSRA data.

7.2 Diagnostic Instruments and the Student Teacher Interviews

7.2.1 Research Question 1: What is the nature of diffusion and osmosis conceptions among Saudi Arabian pre-service science teachers?

The DOPT two-tier diagnostic instruments revealed that in this study the participants' conceptions of diffusion and osmosis were satisfactory although not good. The strongest result for the study was 84.6% of the participants answering both tiers correctly for Item 3 on diffusion and osmosis. Item 5 on diffusion and osmosis gave the study group the most difficulty with 57.3% of the total group answering it correctly.

The results indicate that based on the first tier of the DOPT test alone, the pre-service science teachers have stronger understanding of diffusion and osmosis concepts than of the particle theory of matter concepts. When responses to both tiers were considered, there was further support for their stronger understanding of diffusion and osmosis concepts than of those of the particle theory.

Duit and Treagust (1995) concluded that students may perform well in the first of two tiers; however, it is the second tier that requires them to provide the explanation for their answer in the tier that fails many students. Duit and Treagust (1995) stated that students may fully understand scientific terminology and, for instance, "might be able to provide the names of animals and plants, to write down the Schröedinger equation without any difficulties, or to provide key examples when presented with formulas” (p. 46) but often with no in-depth understanding of the knowledge acquired.

The translated DOPT test was found to have a relatively low, yet acceptable value of Cronbach’s alpha coefficient of 0.54. Adams and Wieman (2011, p.15) provided authority that research designs—such as the one used in this study that featured lower sample sizes and probed multiple concepts with as few research questions as possible—are used to assess collective understanding efficiently as opposed to assessing with detail the concepts of an individual.

The student teachers’ responses to the DOPT diagnostic instrument indicated eight alternative conceptions regarding diffusion and osmosis. Student teacher interview responses regarding alternative conceptions helped to isolate elements of the principles of science that the study group on the whole appears to struggle with in terms of the nature of diffusion and osmosis conceptions. Alternative conception identification provides guidance for pre-service science teachers.

Howe (1996) proposed that instead of challenging alternative conceptions directly as wrong or inadequate, one should "accept the student's ideas as a starting point with a view to helping them expand their knowledge, learn to use it more flexibly, apply it to more situations and, eventually, integrate it into a system of broader, more inclusive concepts" (p. 47). Students need to think what the science concepts mean in terms of their experiences of the concepts, and at the same time fit their everyday experiences into the framework learned in school. They need to move "from the abstract to the concrete and from the concrete to the abstract" (Howe, 1994, p.40). Howe believes that this Vygotskian model would be less confrontational and take into account that "the students need time to get used to and accept new ideas and other ways of understanding phenomena" (p.50). Student teacher interview responses regarding alternative conceptions, in this case, helped to isolate elements of the principles of science that the study group on the whole appears to struggle with in terms of the nature of diffusion and osmosis conceptions.

7.2.2 Research Question 2: What is the nature of the particulate theory of matter conceptions among Saudi Arabian pre-service science teachers?

The diagnostic instruments revealed that the study groups’ conceptions of the particulate theory of matter were unsatisfactory. While for Item 13, 56% of the study group were able to answer both tiers correctly, for Item 16 the proportion of student teachers answering both tiers correctly was 41%. Student teacher interview data suggested that unsatisfactory conceptions of the nature of the particulate theory of matter were a consequence of low-quality laboratory classes. Student teacher interview data suggested poor instructor experiment management, lack of experience in preparing high-quality laboratory classes for the pre-service teachers to observe, a lack of systematic curriculum, and a failure to allow student students to conduct experiments with autonomy were problems. Student teacher interview data also criticized the science teachers whom the pre-service teachers rely on for the correct principles of science.

> "Sometimes the laboratory handouts and exercises asked us to complete questions which needed the theoretical background. (ST6, interview)"

> "For me, the classes and lab work is fine but I know that many of my peers think that the course is unorganized. (ST7, interview)"

Poor instructor experiment management was a problem implied by the student teachers.

> "I can't remember what is happening in the theory classes, but the practical lessons are easier for me (ST9, interview)"

The science teaching staff's lack of experience in preparing high-quality laboratory classes for the pre-service teachers to observe was a problem implied by the student teachers. One of the student teachers indicated that his understanding of the particulate nature of matter would be satisfactory if he had a better opportunity to see the science. He commented, "It is better for me to see what the teachers at the school do." (ST3, interview)

A lack of systematic lesson planning and instruction by the science teachers was inferred by students' responses and further supported by the body of literature Zuckerman (1993) commented "they may not have had the opportunity to construct this knowledge because their teachers were unaware of some subtle pieces (p. 5)". There is a problem in that not all teachers understand the content they are teaching (Haslam & Treagust, 1987).

The interview study group contained ten pre-service science teachers, six of these participants, however, responded that they were not satisfied with the performance of the lecturers. The student teachers suggested that they wanted to be able to manipulate the components of laboratory experiments themselves in order to gain a better understanding of the principles that they will need to teach future generations of students. Some of the student teachers indicated that the teaching staff had failed to allow them to conduct experiments with autonomy.

Nakhleh and Samarapungavan (1999) comment that students need strong imaginations to form an accurate understanding of the particulate nature of matter. Stavy (1994) believes that this is because students often have not grasped the macroscopic properties of materials. Nakhleh (1992) writes that students often hold the alternative conception that matter is continuous as opposed to aggregate.

Twelve alternative conceptions were identified in this study regarding the student teachers' understanding of the particulate nature of matter. Scott, Asoko, Driver and Emberton (1994), Wittrock (1994) and Ebenezer and Erickson (1996) believed that describing and understanding student conceptions will advance the design of science teaching. Scott et al. (1994) argued that if the central focus of planning lessons was the comparison of students' conceptions with the accepted views of science insights into the intellectual demands made on students would be more evident. The information obtained could be used to develop strategies to induce students' dissatisfaction with their alternative conceptions, and give them access to newer and better ideas which are intelligible, plausible and fruitful in offering new interpretations (Hewson, 1981; Posner et al., 1982).

These propositions suggest students studying the particulate nature of matter will achieve enhanced learning outcomes through first gaining a strong appreciation of the macro-scoping properties of materails.

7.2.3 Research Question 3: What are the relationships between Saudi Arabian pre-service science teachers' conceptions of diffusion and osmosis and those of the particulate nature of the matter?

Data analysis revealed that the data gathered from the diagnostic tests showed high correlation between the participants' strong performance on the diffusion and osmosis test items and that on the particulate nature of the matter items. Poor performance on items was also highly correlated.

The results highlighted that the student teachers had a stronger understanding of diffusion and osmosis. The results suggested that the pre-service science teachers in general experienced difficulty in understanding the principles of the particle theory of matter. Hence, priority needs to be given to instruction in the particle theory of matter as inaccurate understandings of these principles are most likely to be passed on from teachers to students if not addressed at the pre-service stage of teacher education.

> I only remember subject matter when I study it by reading it or writing it (ST10, interview).

> The good thing about the lectures in class is that the teachers tell us which parts of the textbook we must know and which parts are not important (ST3, interview).

7.3 TOSRA: The Attitudes of Pre-Service Science Teachers

7.3.1 Research Question 4: What are Saudi Arabian pre-service science teachers' attitudes towards science?

Data was gathered from 192 participants using the TOSRA and this data was validated using Cronbach's alpha coefficient. The data suggested that the pre-service teachers had favourable attitudes towards science and furthermore that these pre-service teachers are currently in good standing to be relied upon to transmit constructive attitudes towards future students in Saudi Arabia.

Hassan (2008) reported that students who perceive science more positively will link career interest with the usefulness of the subject and also found that motivation in science led to further enjoyment of science. For example, a student teacher in this study made a comment in relation to laboratory work. This statement emphasized the enthusiasm that student teachers have in being able to conduct their own experiments and manipulate the inputs and outputs of the practical classes.

> The lab technicians here are really friendly so sometimes they let us conduct our own little experiments when we have finished the main tasks (ST5, interview)

The statement affirms that some pre-service teachers decide to participate in science because they have an interest in the subject and more so that these student teachers are eager to complete tasks and participate in enrichment activities. The student teachers' helpful attitude towards science found in this study is a positive outcome as it provides encouragement for increased participation and increased positive attitude towards science for future generations of students in Saudi Arabia. This encouragement is pleasing.

The data gathered from the interviews helped to characterize the attitudes that the student teachers held towards science. One of the student teachers made a comment which indicated that this group of student teachers were confident. Confidence was a theme. He said, "I think I'm like most students here, I can do the practical tasks easily" (ST3, interview). The student teachers' responses also indicated that they enjoyed science and that they were enthusiastic to study further in science. For example, one student teacher commented. "We did many things ok once but that's not really enough for us to build the confidence that we need" (ST2, interview).

7.4 Research Question 5: What are Saudi Arabia pre-service science teachers' perceptions of the data collection procedure?

The student teachers did make some direct statements indicating their dissatisfaction with the data collection procedure used in this study. It is concluded that the participants' perception towards the data collection procedure was one of general support. The participants did not overtly indicate dissatisfaction with their role in this research. This appears to be true for both the diagnostic testing and the interviews albeit the latter featuring low interest in participation. The student teachers' answers to the interview questions seemed to support that the group was at that time aware of the importance of their role as future science educators. One of the student teachers expressed the need for the government to provide the best possible resources for teachers in training in Saudi Arabia. He commented, "I think because we are training to be teachers we should have the best teachers to show us what to do" (ST4, interview).

ST4's perceptions of the data collection procedure appeared to be positive and his passionate responses suggested diagnosis of the classroom environment, students' conceptions and students' perceptions.

7.5 Summary of the Chapter

This chapter presents and discusses the data gathered from quantitative and qualitative assessments. The pre-service teachers indicated that they believed the management of science instruction in the teachers' colleges — especially instruction in the laboratory classes, the practical classes, their lectures — was not completely satisfactory and was a determinant of the pre-service teachers' poor understandings of these areas of science. The chapter reports that the pre-service teachers tended to enjoy theoretical classes in sciences provided that their instructors were well-organized.

CHAPTER EIGHT

CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

8.1 Introduction

The main purpose of this thesis was to determine the understanding of osmosis, diffusion and particulate theory concepts among pre-service science teachers in Saudi Arabia using modified versions of the two-tier multiple-choice diagnostic instrument on osmosis and diffusion (Odom & Barrow, 1995) and the Test of Science-Related Attitudes (TOSRA) (Fraser,1981). The previous chapter presented the results of this research. The purpose of the present chapter is to reflect on the study results and how the participants answered each of the five research questions, discuss the implications of the research, describe the limitations of the research and provide recommendations for further research.

This chapter consists of four main sections. Section 8.2 summarises and discusses the results of this study in relation to each of five research questions proposed in Chapter 1. The implications of the results of this study are described in Section 8.3. Section 8.4 discusses the recommendations of the study. The suggestions for further research are described in Section 8.5 and the limitations of the study are in Section 8.6. The chapter concludes with a summary.

8.2 Major Findings of the Study

The major findings of this study are organised around the five research questions presented throughout the study.

Research Question 1: What is the nature of diffusion and osmosis conceptions among Saudi Arabian pre-service science teachers?

This research question was answered through the administration of a modified two-tier diagnostic test to 192 pre-service science teachers in 15 teachers' colleges in Saudi Arabia. The modified diagnostic test was developed by combining items on diffusion and osmosis (Odom & Barrow, 1995) and items on particle theory of matter (Othman et al., 2008). The two-tier diagnostic test has the advantage of providing information regarding both the respondent's ability to correctly answer the content tier of the item as well as the respondent's justification for his or her selected option. For the items on diffusion and osmosis (Odom & Barrow, 1995), Items 1 to 8, based on the content tier alone, each had this content tier answered correctly by at least 65.6% of the 192 respondents (Item 5) and up to 93.8% of the 192 respondents (Item 1). The percentage of the 192 respondents that correctly answered both tiers of each item ranged between the lowest 44.9% (Item 7) and the highest 84.6% (Item 3). Othman et al. (2008, p. 1539) used Gilbert's benchmark of more than 75% of the students answering the item correctly to indicate satisfactory understanding of the concept (1977). When Gilbert's standard is applied to these results for diffusion and osmosis understanding, only one of the eight items was answered correctly on both tiers (Item 3). Therefore, overall, the pre-service science teachers' understanding of the concepts of diffusion and osmosis was less than satisfactory.

Othman et al. (2008, p. 1539) used Peterson et al. (1989)'s procedure for identifying an alternative conception. If more than 10% of the respondents chose the same incorrect content tier and/or justification tier, this selection is deemed to indicate an alternative conception. This is because a significant proportion of the respondents held this understanding. The researcher found that six alternative conceptions existed in regards to the respondents' understanding of diffusion and osmosis. These alternative conceptions included alternative understandings about the difference between diffusion and osmosis, the action of the diffusion gradient, and the movement of particles. The most noticeable alternative conception due to its prevalence and inaccuracy was made on Item 5. Of the respondents, 21.6% believed that "After a substance has evenly diffused through water, the molecules of the substance stop moving". The alternative conception shows how the respondents often attributed the visible properties of the bulk materials to the microscopic particles. This was noted by Taber (2001) and Othman et al. (2008) who commented that students expect the behaviour of particles to be similar to the behaviour of bulk materials. For Items 1 to 8 on diffusion and osmosis (Odom & Barrow, 1995), the test results indicated that the impact of this alternative conception was significant.

Research Question 2: What is the nature of the particle theory of matter conceptions among Saudi Arabian pre-service science teachers?

This research question was also answered through the administration of a modified two-tier diagnostic test to 192 pre-service science teachers in 15 teachers' colleges in Saudi Arabia. Data collection and analysis suggested that student teachers are struggling with forming accurate conceptions on the particle theory of matter. This is a systemic weakness as almost every topic in chemistry relies on an accurate understanding of the principles of the particle theory of matter (Harrison & Treagust, 2002). As noted by Taber (2001) and Othman et al. (2008), the problem for many students in science is assuming that macroscopic properties such as the effect of gravity on mass represent the events on the micro-scale. In other words, students expect the behaviour of particles to be similar to the behaviour of bulk materials. The effect of this expectation of the students for the particle theory of matter items (Othman et al., 2008), Items 9 – 17, were more intrusive. The percentage of respondents who were able to correctly answer the content tier of each item ranged between the lowest 52.4% (Item 15) and the highest 88.5% (Item 14). However, there were four items (Items 10, 11, 15 and 16) in which less than 60% of the respondents were able to answer even the first tier alone correctly. For both tiers, in none of the items were there more than 75% of the respondents able to answer both tiers correctly. Therefore, Gilbert’s (1977) benchmark of more than 75% of the students answering the item correctly was not achieved in any of the items. Less than 60% of the pre-service science teachers were able to answer both tiers of any items correctly with the exceptions of Item 9 (62.1%) and Item 14 (63%). The level of student understanding of the principles of the particulate theory of matter was unsatisfactory.

Using Peterson et al.’s (1989) procedure for identifying evidence for an alternative conception (as cited by Othman. et al., 2008, p. 1539), there were 12 alternative conceptions in this study for the topic of the particulate theory of matter. The student teachers appeared to have confused the mass and heat energy behaviours of particles with the behaviours observed on the macro-scale. Three of the items

(Items 9, 10, and 12) were answered in ways which gave evidence to multiple alternative conceptions.

Research Question 3: What are the relationships between Saudi Arabian pre-service science teachers' conceptions of diffusion and osmosis and those the particulate nature of matter?

This research question was answered through conducting a Pearson Product-Moment correlation analysis. For the purpose of a research project, a correlation would be considered significant at the 0.01 level (2-tailed). In this case the correlation between respondents' test scores of items on diffusion and osmosis and their test scores of items on particulate nature of matter was found to be 0.417. And so it was statistically significant ($p < .01$; two-tailed) showing that they are positively correlated. In other words, the respondents who scored higher on the diffusion and osmosis items also were found to score higher on the particulate nature of matter items.

Research Question 4: What are Saudi Arabian pre-service science teachers' attitudes towards science?

This research question was answered through the administration of TOSRA—an instrument designed to measure science-related attitudes of students—to 217 respondents. The TOSRA has an advantage over other science attitude questionnaires as it can provide attitudinal aims. To test the reliability and validity of the TOSRA, factor of analysis and the Cronbach alpha coefficient were used (Cronbach, 1951). For 30 items, the internal consistency was found to 0.65. The mean and standard deviations of the TOSRA results were also determined to assess the discriminant validity of the TOSRA. These results also supported that the respondents had positive attitudes towards science and suggested that these pre-service teachers would enhance the attitudes and achievement of their future students in the discipline due to their encouraging perspective.

Research Question 5: What are Saudi Arabia pre-service science teachers' perceptions of the data collection procedure?

This research question was answered through face-to-face interviews with 10 of the respondents. The interview was structured into part one—the level of satisfaction that the pre-service teachers held regarding their participation in the study, and part two—questioning the student teachers about their responses in the diagnostic test. Part one answered questions related to Saudi Arabia pre-service science teachers' perceptions of the data collection procedure. The answers to the questions did not address the objective and this was one of the limitations of the study. However, the first part of the interviews revealed that the student teachers were not on the whole satisfied with the teaching staff at the teachers' colleges.

8.3 Implications of the Study

The DOPT two-tier instrument is able to diagnose the extent of student teachers' understanding of concepts in the two topics. Student teachers performed better on the content tier of the test items than on both tiers of content and justification. Student teachers might have learned the 'correct' answers through rote learning. Student teachers' lack of understanding of the particulate theory of matter was probably adversely affecting their performance in the physical sciences.

A second implication of the study is that it validated the use of the Test of Science- Related Attitudes (TOSRA) for the first time in Saudi Arabia. TOSRA was developed and validated in Australia and the United States (Fraser, 1981), then New Zealand (Lowe, 2004). Attitude in pre-service science teachers is a valuable measure of the quality of educational programs. Techniques, methods and initiatives, including this study, that are aimed to provide data regarding the views and beliefs of the next generation of science educators are extremely valuable as a scoreboard of education design effectiveness.

8.4 Recommendations

(1) Avoid making presumptions on student understanding of scientific principles

It is important that teachers make the knowledge base explicit. Teachers must avoid making presumptions on student understanding of scientific principles. The results of the study highlight that a proportion of student teachers are struggling with diffusion and osmosis and even a greater proportion of the same group of student teachers struggle with the particulate theory of matter. Reif and Larkin (1991) found that students are able to better grasp content when they have an understanding of the expectations of the course.

(2) Increase attention on the way the particle theory of matter is taught

It is important the students understand the principles of the particle theory of matter as these concepts are precursor knowledge for further studies in the physical sciences. The results in this study highlighted that student teachers are struggling with these principles with no item correctly answered on both tiers by more than 62% of the pre-service teachers.

(3) Focus on the way that subject-specific terminology is instructed

The terminology of science poses a problem for learners. The diagnostic test results revealed that the student teachers had difficulty choosing the correct words. This was also found in the interview data. Teacher educators could improve this by focusing on the way that subject specific terminology is instructed.

(4) Investigate students' understandings and interpretations of the word—theory

The student teacher responses revealed that a proportion of the group attributed a negative connotation to the word, *theory*. There appears to be gap between the practical aspects of the course and the theoretical components. Student Teacher 6 commented "Sometimes the laboratory handouts and exercises asked us to complete questions which needed the theoretical background (ST6, interview)". Another one of the student teachers commented "I can't remember what is happening in the theory classes, but the practical lessons are easier for me (ST9, interview)". Investigating the student teachers' understandings and interpretations of the word—theory—may help to address the origins of any negative views.

(5) Use students' interest in practical lessons to leverage their understanding of the theory

The results highlighted that the student teachers favoured the hands-on practical lessons. They found these lessons easy as revealed by Student Teacher 3's comment: "I think I'm like most students here, I can do the practical tasks easily" (ST3, interview) and that of Student Teacher 9: "I can't remember what is happening in the theory classes, but the practical lessons are easier for me" (ST9, interview).

(6) Changing assessment practices

The finding that a greater proportion of the student teachers were able to answer the first tier of the item correctly but not able to correctly answer the justification tier suggested that teacher educators teaching diffusion and osmosis and the particulate nature of matter might not be encouraging a deep understanding of the principles in their student teachers. This may be related to both the syllabus and the assessment. Often assessment procedures distort instruction. One reason for this is that teachers are mindful of their school's academic ranking and reputation. Treagust (1995) referred to this phenomenon in relation to the study of chemistry stating: "assessment procedures distort and narrow instruction" (p. 327).

8.5 Suggestions for Further Research

(1) Investigation into the pre-course and post-course attitudes of pre-service science teachers

The study of students' attitudes towards science in Saudi Arabia needs to be expanded on. An implication of this study was that it validated the use of the Test of Science-Related Attitudes (TOSRA) for the first time in Saudi Arabia. However, there is a need to explore student attitudes towards science in more depth and to have an ongoing supply of data concerning the attitudes of students towards science before undertaking particular courses of study by way of a pre-course test, and after these courses of study, a post-course test.

(2) Investigation into the pre-course and post-course conceptual understandings of pre-service science teachers using diagnostic testing, first-hand research on the correlation of attitude and achievement in science

While correlating general science achievement and attitude exceeded this study's scope, for future studies, determining the extent of a link between the two in the science classroom in Saudi Arabia would be very useful. In order for this area of research, both conceptual understanding of the principles of scientific concepts and students' attitudes to science education, to attain its required status and required influence on the teaching profession in Saudi Arabia, there needs to be more supporting empirical data that highlights the link between certain attitudes towards science and achievement.

(3) Conduct research involving an extended interview sample

Conducting research involving an extended interview sample would provide very useful data on the opinions and perspectives of pre-service teachers in the science classroom. This project was able to gather data for approximately five minutes from ten pre-service science teachers; however, this quantity failed to meet the research standard of saturation. The researcher found that each of the participants still had useful information to provide; however, the design of the research failed to accommodate this. A new study that allows for interviews of extended length, approximately 20 to 30 minutes, and that involves at least 20 participants would have a much greater opportunity to capture and describe emerging themes. Another approach to this would be to conduct focus-group interviews. The choice of one-on-one interviews or focus-group interviews would depend on the parameters, scope and resources of the research project. This is an area where a gap still exists in the body of research of science education in Saudi Arabia.

(4) Investigate the different research designs, specifically, those which make the research design less invasive on the participants' schedules

There is a need to develop research designs which are less invasive on the participants' schedule. One method would be to carry out the assessment of conceptual understandings and the assessment of student attitudes on different occasions or even in different research projects. This area of further research would be best if it is first attempted through a research design which gathers data from the same study sample, that is, the same students, with these additional features. This area of further research offers to provide faster, more up-to-date, and more relevant data concerning science education in Saudi Arabia for education planners. This stream of data is vital to ensure optimal transparency and improvement of the overall system.

8.6 Limitations of the Study

(1) The content that teacher had taught to students

The study did not describe the syllabus in detail. This has been done in other studies such as Tan's (2000) study when the O-level practical examinations were explained and described. This would help to highlight areas of curriculum that may need change.

(2) The concepts and propositions assessed

Not all of the concepts on the principles of diffusion and osmosis or the particulate nature of matter were tested. Therefore, there may be an argument that the concepts and propositions assessed were incomplete.

(3) The size of the sample

One hundred and ninety-two student teachers completed the DOPT two-tier diagnostic test and TOSRA. This sample size in this study, 192, was smaller than that in Othman et al.'s (2008) study on student understanding of particulate nature of matter and chemical bonding in Singapore which gathered data from 260 respondents. This sample size in this study was also much smaller than Tan's (2000) study on qualitative analysis which gathered data from 915 respondents. However, the strength of the data collection process in this study is that the data were collected from 15 teachers' colleges in Saudi Arabia from the very east to the very west of the country. The data collection process involved the researcher travelling at times over 1000 kilometers from one college to the next. Therefore, there is no reason to suggest that the sample is not representative of the majority of third year pre-service science teachers in Saudi Arabia. Generalization of the findings of this study to teacher colleges in other nations outside of Saudi Arabia, however, should be made with caution.

(4) The demands on reading/comprehension skills

The two-tier diagnostic test with multiple-choice items delivered in pencil-and-paper format may not be valid due to respondents' misinterpretation. The demands on reading/comprehension skills in multiple-choice items can be high according to Taber (1999). The two-tier diagnostic test delivered in this study featured multiple-choice items with a limited number of distracters, therefore, respondents guessing the answers would have skewed the results as found by Taber (1999).

(5) The interpretation of translated versions of the assessment instruments

The interpretation of translated versions of the assessment instruments could have skewed results for two reasons. Firstly, the format of the Arabic version DOPT Diagnostic Test provided to the student group was exactly same format of the test affixed. The aspect that limited the study was that even though the overall document was translated into Arabic, there were a number of English terms retained on the Arabic translated version. These terms were limited to the smaller font and were limited to isolated words and phrases directly related to and in close proximity to the diagrams on the test. Nonetheless, even though it may be worthwhile to mention that the pre-service teachers who completed these tests in teacher colleges in Saudi Arabia were third and fourth year college students and were presumably familiar with the English terms, the presence of these retained English terms may have had an impact on student understanding. The translations of the TOSRA, however, featured no such retentions.

The second reason that interpretation of translated versions of the assessment instruments could have skewed results was that inconsistencies could have resulted from the translation process independent of students. The need for accurate use of vocabulary in science instruction is relevant. The procedure in this research involved the diagnostic instrument and the TOSRA instruments to be translated from English to Arabic, and then back translated from Arabic to English to identify areas where there might be inconsistencies in translation. Although the researcher did not identify significant areas of inaccurate or ambiguous translation, the existence of slightly different meanings for each word would have undoubtedly affected the respondents' word-by-word understanding. The diagnostic instruments and the TOSRA are assessments which are highly dependent on the selection of chunks of words and phrases which indicate the best answer. Therefore, the results need to be viewed with some caution.

(6) The lack of follow-up interviews

The optional basis of the interview process resulted in a limited number of interviews being conducted and each interview often being limited in time. From the 192 respondents, 10 student teachers participated in interviews. Each interview ranged between five and ten minutes; however, the researcher with the benefit of hindsight recognized that interviews of ten to twenty minutes would have been required to gather more information. The optional basis of the interviews meant that both the number of participants and the length of the interviews were insufficient. The data gathered was, therefore, less than optimal. The follow-up interview data could only be used as a basis for areas where further research is required. Another limitation of the interview data was that this component of the data collection procedure failed to fully serve the purpose of triangulation in that reliability and validity would likely be higher with more interviews.

8.7 Summary

This chapter summarises how each of the five research questions was addressed by the research design. Conclusions for each of the research questions are given. The chapter lists five recommendations for the teaching and learning of diffusion and osmosis and the particulate nature of matter in teachers' colleges in Saudi Arabia. The chapter outlines the implications of the project, discusses suggestions for further research and explains the limitations of the study.

REFERENCES

Adams, W. K., & Wieman, C. E. (2011). Development and validation of instruments to measure learning of Expert-Like Thinking. *International Journal of Science Education, 33*(9), 1289-1312.

Adey, P. (1992). Alternative constructs and cognitive development:commonalities, divergences, and possiblities for evidence. *Research in Science Education, 20*(3), 305-316.

Adbo, K., & Taber, K. S. (2009). Learners' mental models of the particle nature of matter: A study of 16-year-old Swedish science students. *International Journal of Science Education, 33*(6), 757 - 786.

Al-hurr, A., & Ar-rumi, A. (2002). Using diagnostic tests to evaluate the mastery of learning for grade eight students in public schools in Qatar. *Risalat Ul-Khaleej Al-Arabi, 85*, 37-87.

Alriyadh Teacher's College. (2007). Retrieved. October 9, 2007, from http://www.tcr.edu.sa/.

Andersson, B. R. (1986). Pupils' explanations of some aspects of chemical reaction. *Science Education, 70*(5), 549-563.

Anderson, C. W., & Smith, E. L. (1983). Children's preconceptions and content area textbooks. In G. Duff, L. Rochler & J. Mason (Eds.), *Comprehension instruction: Perspectives and suggestions* (pp. 187-201). New York: Longman.

Anderson, G. (1990). Fundamentals of educational research. Hampshire. London. The Falmer Press.

Anderson, G., & Arsenault, N. (2004). *Fundamentals of educational research (2nd ed.)*. New York: Routledge Falmer.

Ary, D., & Jacob, L. C. (1979). *Introduction to research in education (2nd ed.)*. New York: Holt, Rinehart and Winston.

Ary, D., Jacobs, L. C., Razavieh, A., & Sorensen, C. (2009). *Introduction to research in education* (8 ed.). Belmont, USA: Wadsworth.

Ausubel, D. P (1968). *Education psychology: A cognitive view*. New York: Holt, Rineheart & Winston.

Bakar, E., Bal, S. and Akcay, H. (2006) Preservice Science Teachers Beliefs About Science -Technology and Their Implication in Society. *Eurasia Journal of Mathematics, Science and Technology Education,* 2(3). http://www.ejmste.com

Barrow, G. M. (1991). Intellectual integrity or mental sevility. *Journal of Chemical Education, 68*(6), 449-453.

Bell, B. (1984). Aspects of secondary students' understanding of plant nutrition:Summary report *Children's Learning in Science Project,Centre for Studies and Mathematics Education,The University of Leeds*: Leeds, England.

Bell, B., & Cowie, B. (2001). *Formative assessment in science education*: Dordrecht, Netherlands: Kluwer Academic Publishers.

Black, P. & Wiliam, D. (1998). Inside the black box: Raising standards through classroom assessment. *Phi Delta Kappan*, *80*, 139-144.

Bingilmas, K. (2009). Barriers to the successful integration of ICT in teaching and learning environments: A review of the literature. *Eurasia Journal of Science, Mathematics, and Technology Education, 5*(3), 235 – 245.

Bodner, G. M. (1992). Why changing the curriculum may not be enough. *Journal of Chemical Education, 69*(3), 186-190.

Booker, G., Bond, D., Briggs, J., & Davey, G. (1998). Teaching primary mathematics. Sydney: Longman

Brislin, R. W. (1970). Back translation for cross-culture research. *Journal of Cross-Culture Psychology,* 1, 185-216.

Brislin, R. W. (1980). Translation and content analysis of oral and written material. In H. C. Triandis & J. W. Berry (Eds.), *Handbook of cross-culture psychology: Methodology* (pp.389-444). Boston. MA: Allyn and Bacon Inc.

Cardac, O. (2009). Science Students' Misconceptions of the Water Cycle According to their Drawings. *Journal of Applied Sciences,* 9(5), 865-873

Carr, K. (2003). There are many ways to make assessment more authentic. *Teachers and Curriculum, 6*, 35-38.

Center for Science, Mathematics and Engineering (1997). Misconceptions as Barriers to Understanding Science. *Science teaching reconsidered: A handbook* (Chapter 4). The National Academies Press. Retrieved October 4, 2008, from http://www.nap.edu

Chandrasegaran, A. L., Treagust, D. F. & Mocerino, M. (2005). *Diagnostic assessment of secondary students' use of three levels of representation to explain simple chemical reactions.* Paper presented at the 36th annual conference of the Australasian Science Education Research Association (ASERA), Hamilton, New Zealand.

Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reaction using multiple levels of resentation.. *Chemistry Education Research and Practice, 8*(3), 293-307.

Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2008). An evaluation of a teaching intervention to promote students' ability to use multiple levels of representation when describing and explaining chemical reactions. *Research in Science Education*, 38, 237-248.

Chen, C-C., Lin, H-S. & Lin. M-L. (2002). Developing a two-tier diagnostic instrument to assess high school students' understanding – the formation of images by a plane mirror. *Proceedings of the National Science Council, ROC (D), 12*(3), 106–121.

Chi, M. T. H., Solotta, J. D., & de Leeuw, N. (1994). From things to processes: A theory of conceptual change for learning science concepts. *Learning and Instruction, 4*, 27-43.

Chiu, M. H. (2001). Exploring mental models and causes of high school students' misconceptions in acids-bases, particle theory and chemical equilibrium. *Project Report in National Science Council.*

Chiu, M. H. (2002). Exploring mental models and causes of high school students' misconceptions in acids-bases, particle theory and chemical equilibrium. *Project Report in National Science Council.*

Chiu, M.-H. (2005). A national survey of students' conceptions in chemistry in Taiwan. *Chemical Education International, 6*(1), 1-8.

Chiu, M. L., Chiu, M. H. & Ho, C. Y. (2002). Using cognitive-based dynamic representations to diagnose students' conceptions of the characteristics of matter. *Proceedings of the National Science Council Part D: Mathematics, Science and Technology Education,* 12(3), 91–99.

Chiu, M.-H., Guo, C.-J., & Treagust, D. F. (2007). Assessing students' conceptual understanding in science:An introduction about a national project in Taiwan. *International Journal of Science Education, 29*(4), 379-390.

Cho, H., Kahle, J. B., & Nordland, F. H. (1985). An investigation of high school biology textbooks as sources of misconceptions and difficulties in genetics and some suggestions for teaching genetics. *Science Education, 69*(5), 707-719.

Christianson, R. G. & Fisher, K. M. (1999). Comparison of student learning about diffusion and osmosis in constructivist and traditional classrooms. *International Journal of Science Education*, 21(6), 687-698.

Cohen, L., Manion, L., & Morrison, K. (2005). *Research methods in education (5th ed.)*. London: Routledge Falmer.

Costa, N., Marques, L., & Kempa, R.F. (2000). Science teachers' awareness of findings from educational research. *Chemistry Education: Research and Practice in Europe,* 1, 31-36.

Coulson, R. (1992). Development of an instrument for measuring attitudes of early childhood educators towards science. *Research in Science Education*, 22, 101-105.

Creswell, J. (2005). Educational research: Planning, conducting, and evaluating, qualitative and quantitative Research (2nd ed.). Sydney, Australia: Pearson Merrill Prentice Hall.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16, 291-334.

Crooks, T. J. (2004). *Tension between assessment for learning and assessment for qualification*. Retrieved April 23, 2009, from http://www.spbea.org.fj/aceab/Crooks.pdf

Denzin, N. K. (1997). Triangulation in educational research. In J. P. Keeves (Ed.) *Educational research methodology and measurement: An international handbook (2nd ed.).* Oxford; U.K. Elsevier Science.

Denzin, N., & Lincoln, Y. (1998). Introduction: Entering the field of qualitative research. In N. Denzin & Y. Lincoln (Eds.), *Collecting and interpreting qualitative materials* (pp. 1-34). London: Sage Publishers.

Denzin, N., & Lincoln, Y. (Eds.) (2000). *Handbook of qualitative research (2nd ed).* San Francisco, CA: Sage Publishers.

DET (2010). The Department of Education: Professional Learning Institute. Retrieved October 23, 2010, from http://www.det.wa.edu.au/pli/detcms/navigation/professional-learning-register/teachers/primary-support-programs/

DeVos, W., & Verdonk, A. H. (1985). A new road to reaction. *Journal of Chemical Education, 62*(3), 238-240.

Dix, S. (2003). The effectiveness of formative assessment:Does peer response improve the students' writing? *Teachers and Curriculum, 6*, 29-34.

Doran, R. L. (1972). Misconceptions of selected science concepts held by elementary school students. *Jounal of Research in Science Teaching, 9*(2), 127-137.

Driver, R. (1995). Constructivist approaches to science teaching. In L. P. Steffe & J. Gale (Eds.), *Constructivism in Education* (pp. 385-400). Hillsdale, NJ: Lawrence Erlbaum Associates.

Driver, R., Aquires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science: Research into children's ideas*. London and New York: Routledge.

Driver, R., & Easley, J. (1978). Pupils and paradigms: A review of literature related to concept development in adolescent science students. *Studies in Science Education, 5*, 61-84.

Driver, R., & Erickson, G. (1983). Theories-in-action: Some theoretical and empirical issues in the study of students' conceptual frameworks in science. *Science Education, 10*, 37-60.

Duit, R. (1995). The constructivist view: A fashionable and fruitful paradigm for science education research and practice. In L. P. S. J. Gale (Ed.), *Constructivism in education* (pp. 385-400). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Duit, R . (2004).Bibliography; students' and teachers' conceptions and science education (STCSE). Kiel: Leibinz- Institute for Science Education (IPN)

Duit, R., & Confrey, J. (1996). Reorganising the curriculum and teaching to improve learning in science and mathematics. In D. F. Treagust, R. Duit & B. J. Fraser (Eds.),*Improving learning in science and mathematics* (pp.79-93). New York: Teachers College Press.

Duit, R., & Treagust, D. F. (1995). Students' conceptions and constructivist teaching approaches. In B. J. Fraser & H. J. Walberg (Eds.), *Improving science education*. Chicago: The National Society for the Study of Education.

Duit, R., & Treagust, D. F. (1998). Learning in science: from behaviorism towards social constructivism and beyond. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (Vol. 1, pp. 3-25). Dordrecht, Netherlands: Kluwer Academic Publishers.

Duit, R., & Treagust, D. T. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education, 25*(6), 671-688.

Education Services Australia, (2009). the National Assessment Program Science Literacy. Retrieved August 9, 2009, from http://www.curriculum.edu.au/verve/_resources/NAP_ScienceLit_2009_Assessment_

Kareem, I. E. A. (1999). *The effect of teaching chemistry by using electronic accounting in the results of first year secondary girl students and their attitude towards the subject of chemistry at a school in the city of Riyadh*. Unpublished Master Thesis, King Saud University, Riyadh.

El Sayeh, E., M. (1987) Improvement of general agricultural secondary schools curriculum as a requirement of the biology literacy, PhD Thesis. Faculty of Education, Ainshams University, Cairo, Egypt

Elharigi, S., & Moussa, R. (1995). The attitude of students (male & famale) of the intermediate and secondary stages in the country and city towards science and its relationship with their achievement in the subject of science in the region of Alahsaa in the Kingdom of Saudi Arabia. *Risalat Ul-Khaleej Al-Arabi* (54), 15-63.

Eltinge, E. M., & Robert, C. W. (1993). Linguistic content analysis: A method to measure science as inquiry in textbooks. *Journal of Research in Science Teaching, 30*(1), 65-83.

Evans, G., & Durant, J. (1995). The relationship between knowledge and attitudes in the public understanding of science in Britain. *Public Understanding of Science, 4*, 57-74.

Fetherston, T. (2007). *Becoming an effective teacher.* Melbourne, Australia: Thomson.

Fetherstonaugh, T. & Treagust, D. F. (1992). Students' understanding of light and its properties: Teaching to engender conceptual change. *Science Education,* 76(6), 653–672.

Fontana, A., & Frey, J. H. (2000). The interview: From structured questions to negotiated text. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research (2nd ed.)*. London: Stage Publications, Inc.

Franklin, B. J. (1992). The development, validation and application of a two-tier diagnostic instrument to detect misconceptions in the areas of force, heat, light and electricity. Louisiana State University and Agricultural and Mechanical College.

Fraser, B. J. (1977b). Attitude to the Social Implications of Science: Its Measurement and Correlates. *Australian Science Teachers Journal, 23*(2), 9-96.

Fraser, B. J. (1977a). Selection and validation of attitude scales for curriculum evaluation. *Science Education, 61*, 317-329.

Fraser, B. J. (1981). *TOSRA: test of science-related attitudes handbook*. Hawthorn, Australia: The Australian Council for Educational Research Limited.

Fraser, B. J. (1989). *Learning environment research in science classrooms: Past progress and future prospects*. NARST Monograph, Number Two. Manhattan, KS: National Association for Research in Science Teaching (NARST), Kansas State University.

Fraser, B.J. (1998). Science learning environments: Assessment, effects and determinants. In B.J. Fraser & K.G. Tobin (Eds.), *International handbook of science education* (pp. 527–564). Dordrecht, The Netherlands: Kluwer.

Fraser, B. J., & Butts, W. L. (1982). Relationship between perceived levels of classroom individualization and science-related attitudes. *Journal of Research in Science Teaching*, *19*(2), 143-154.

Fraser, B. J., & Tobin, K. G. (1991). Combining qualitative and quantitative methods in classroom environment research. London: Pergamon.

Gall, M. D., Borg, W., R., & Gall, J, P (1996). Educational research: An introduction (6th ed). New York, USA: Longman Publishers.

Gallagher, J. J. (1991). Uses of interpretive research in science education. In J. Gallagher (Ed.), *Interpretive research in science education-NARST monograph* (pp. 1-17). Columbus, OH: National Association for Research in Science Teaching.

Garnett, P. J., Garnett, P. J., & Hackling, M. W. (1995). Students' alternative conceptions in chemistry: a review of research and implications for teaching and learning. *Study in Science Education, 25*, 69-95.

Garnett, P. J., & Treagust, D. F. (1992). Conceptual difficulties experienced by senior high school students of electrochemistry: Electrochemical (Galvanic) and electrolytic cells. *Journal of Research in Science Teaching, 29*, 1079-1099.

Gibson, H. L., & Chase, C. (2002). Longitudinal Impact of an Inquiry-Based Science Program on Middle School Students' Attitude Toward Science. *Science Education, 86*(5), 693-705.

Gilbert, J. K. (1977). The study of student misunderstandings in the physical sciences. *Research in Science Education,* 7, 165 – 171.

Gilbert, J. K., Osborne, R. J., & Fensham, P. J. (1982). Children's science and its consequences for teaching. *Science Education, 66*(4), 623-633.

Gilbert, J. K., & Swift, D. J. (1985). Towards a Lakatosion analysis of the Piagetian and alternative conceptions research program. *Science Education, 69*, 681-696.

Good, W. J., & Hart, P. K. (1952). *Methods in social research*. London: McGraw Hill.

Guba, E. G., & Lincoln, Y. S. (1989). *Fourth generation evaluation*. Beverly Hills, CA: Sage Publications.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 105-121). Beverly Hills, CA: Stage Publications.

Gulf Cooperation Council (2002). Overall development of education in the study on directions contained in the decision of the supreme council. Retrieved January 20, 2008 from http://library.gcc-sg.org/Arabic/APicshow.asp?mycover=17

Halloun, H. & Hestenes, D. (1985). The initial knowledge state of college physics students. *American Journal of Physics, 53*, 1043–1055.

Hamdan, A. (2005). Women and education in Saudi Arabia: Challenges and Achievements. *International Education Journal, 6*(1), 42-64.

Harlen, W. (2005). *Formative and summative assesssment:A harmonious relationship?* Paper given at the assessment systems for the future seminar,Fitzwilliam College, Cambridge.

Hashweh, M. (1988). Descriptive studies of students' conceptions in science. *Journal of Research in Science Teaching, 25*, 121-134.

Hashweh, M. Z. (1986). Toward an explanation of conceptual change *European Journal of Science Education, 8*(3), 229-249.

Haslan, F., & Treagust, D. F. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of Biological Education,, 21*, 203-211.

Hassan, G (2008). Attitudes towards science among Australian tertiary and secondary school students. *Research in Science & Technological Education, 26(2), 129-147*

Hassan, M., A. (1987). *The influence of science curriculum on the students' biology cultures and literacy*. MSc. Thesis Institute for Educational Research and Studies. Cairo University.

Hassn, A. M. A. H. (2004). *Statistical Manual in the analysis of data using SPSS*. Riyadh: Alrushed library.

Hattie, J. (1999). *Infuences on student learning*. Retrieved May 17, 2008, from http://www.education.auckland.ac.nz/webdav/site/education/shared/hattie/docs/influences-on-student-learning.pdf.

Hestenes, D., Wells, M. & Schwackhamer, G. (1992). Force concept inventory. *The Physics Teacher, 30*, 141–158.

Hewson, P. J. (1996). Teaching for concepual change In D. F. Treagust, R. Duit & B. J. Fraser (Eds.), *Improving teaching and learning in science and mathematics*. New York: Teacher College Press.

Hill, M. (2002). *The Education Standards Act and enchancing learning:Flipsides of the same coin or chalk and cheese?* Retrieved August 25, 2009, from http://www.nzpf.ac.nz/archive/mag2002/June02_Education_Standards.pdf.

Hogan, K. (1999). Thinking aloud together: A test of an intervention to foster students' collaborative scientific reasoning. *Journal of Research in Science Teaching, 36*(10), 1085-1109.

Hogan, K. (2000). Exploring a process view of students' knowledge about the nature of science. *Science Education, 84*(1), 51-70.

Howe, C. (1996). Development of Science Concepts within a Vygotskian Framework. *Science Education. 80*(1), 35-51.

Huddle, P. A., White, M. D., & Rogers, F. (2000). Using a teaching model to correct known misconceptions in electrochemistry. *Journal of Chemical Education, 77*(1), 104-110.

Jackson, S. L. (2006). Research methods and statistics: A critical thinking approach (2nd ed.). Belmont, CA: Thomson Wadsworth.

Jarvis, T., & Pell, A. (2005). Factors influencing elementary school children's attitudes to science before, during and following a visit to the UK National Space Centre Journal of Research in Science Teaching. *Journal of Research in Science Teaching, 42*(1), 53-83.

Johnstone, A. H. (1997). Chemistry teaching - Science or Alchemy. *Journal of Chemical Education, 74*(3), 262-268.

Johnstone, A. H. (1999). The nature of chemistry. *Education in Chemistry, 36*(2), 45-47.

Johnstone, A. H., Hogg, W. R., MacGuire, P. R. P., & Raja, S. H. (1997). How long is a chain? Reason in science. *School Science Review, 78*(285), 73-77.

Joseph, F., Ciofalo, J. F., & Wylie, C. (2006). Using diagnostic assessment; One question at a time. *Teacher College Record*. Retrieved September 15, 2009, from http://www.edudata.educ.ubc.ca/reading_room/reading_articles/Using%20Diagnostic%20Classroom%20Assessment_%20One%20Question%20at%20a%20Time.pdf

Kattmann, U., Duit, R., Gropengießer, H., & Komorek, M. (1995; April). *A model of educational reconstruction*. Paper presented at the Annual Meeting of the National Association of Research in Science Teaching (NARST).

Koballa, T., Gaber, W., Coleman, D. C., & Kemp, A. C. (2000). Prospective gymnasium teachers' conception of chemistry learning and teaching. *International Journal of Science Education, 22*(2), 209-224.

Kvale, S. (1996). Interviews: An introduction to qualitative research interviewing. London: Sage Publication.

Larrabee, T. G., Stein, M., & Barman, C. (2006). A computer-based instrument that identifies common science misconceptions. *Contemporary issues in Technology and Teacher Education, 3*, 306-312.

Lauer, J., & Asher, W. (1988). *Composition research: Empirical designs*. New York: Oxford.

Lawson, A. E. (1994). Research on the acquisition of science knowledge: epistemological foundation of cognition. In D. L. Gabel (Ed.), *Handbook fo research on science teaching and learning* (pp. 131-176). New York: Macmillan.

Levins, L. & Pegg, J. 1993. Students' understanding of concepts related to plant growth. *Research in Science Education* 23, 165-173.

Lewin, K. M. (1990). Data collection and analysis in Malaysia and Sri Lanka. In G. Vulliamy, K. Lewin & D. Stephens (Eds.), *Doing education research in developing countries: Qualitative strategies* (pp. 116-142). London: The Falmer Press.

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*, l4O, 44-53

Lin, S.-W. (2004). Development and application of a two-tier diagnostic test for high school students' understanding of flowering plant growth and development. *International Journal of Science and Mathematics Education, 2*, 175-199.

Linke, R. D., & Venz, M. I. (1978). Misconceptions in physical science among non-science background students: *Research in Science Education, 8*, 183-193.

Linke, R. D., & Venz, M. I. (1979). Misconceptions in physical science among non-science background students: *Research in Science Education,* 9, 103-109.

Littlewood, J. (2003). Will the new planning and reporting requirements improve student achievement in New Zealand schools. *Teachers and Curriculum,* 6, 49-51.

Long, J.C., Okey, J. R., & Yeany, R. H. (1981). The effects of a diagnostic-prescription teaching strategy on student achievement and attitude in biology. *Journal of research in Science Teaching*, *18*(6), 515-523.

Lovell, K., & Lawson, K. S. (1970) *Understanding research in education*. London: University of London Press.

Lowe, J. P. (2004). The effect of cooperative group work and assessment on the attitudes of students towards science in New Zealand. Curtin University, Perth.

Mann, M., & Treagust, D. F. (1998). A pencil and paper instrument to diagnose students' conceptions of breathing, gas exchange and respiration. *Australian Science Teachers Journal, 44*(2), 55-59.

Martin-Dunlop, C, (2004). Perceptions of the learning environment, attitudes towards science, and understanding of the nature of science among prospective elementary teachers in an innovative science course. Curtin University of Technology, Curtin University of Technology, Perth, Australia.

Hashem, A. M. A. (2004). Statistical Manual in the analysis of data using SPSS. Riyadh: Alrushed library.

Masu, C. K. (1989). An investigation of the attitudes of senior secondary school science teachers' to the implementation of the PKA-IPA's model of teaching in Kupang, Indonesia. Unpublished PhD Thesis, Curtin University of Technology, Perth, Australia.

Mathison, S. (1988). Why triangulation? *Educational Researcher*, *17*(2), 13-17.

McMahon, T. (2009, July). Evidence to action:Legislation for ongoing improvement. Retrieved October 5, 2010, from http://www.tki.org.nz/r/assessment/research/research15e.php.

McMillan, J. H., & Schumacher, S. (1993). *Research in education: A conceptual introduction.* New York: Harper Collins.

Merriam, S. B. (1988). *Case study research in education: A qualitative approach*. San Francisco, CA: Jossey-Bass Inc.

Merriam, S. B. (1990). *Case study research in education*. San Francisco, CA: Jossey Bass Inc.

Merriam, S. B. (1998). *Qualitative research and case study application in education*. San Francisco, CA: Jossey-Bass Inc.

Millar, R., & Hames, V. (2001). Using diagnostic assesssment to improve students' learning in science. *School Science Review, 84*(307), 21-24.

Millar, R. & Hames V. (2001). Using diagnostic assessment to improve students' learning in science: some preliminary findings from work to develop and test diagnostic tools. Paper presented at the Third conference of the European Science Education Research Association (ESERA), Thessaloniki, Greece.

Ministry of Education Jordan (2001). *Diagnostic remedial assessment of 7th grades students*. Retrieved January 18, 2008, from http://www.moe.gov.jo/

Ministry of Education New Zealand (2010). *The assessment tools for teaching and learning*. Retrieved September 9, from http://www.tki.org.nz/r/asttle/

Motawaa, D. D. M. (1995). Developing of emotional and academic perspectives related to modern biological requirements of the education schools students – biology department. Unpublished PhD Thesis, Mansoura University, Egypt.

Munro, B. H. (2005). *Statistical methods for health care research (5th ed.)*. New York: Lippincott Williams & Wilkins.

Masu, C. K. (1989). An investigation of the attitudes of senior secondary school science teachers' to the implementation of the PKA-IPA's model of teaching in Kupang, Indonesia. Unpublished PhD Thesis, Curtin University of technology.

Nakhleh, M. B. (1992). Why some students don't learn chemistry: chemical misconceptions. *Journal of Chemical Education, 69*(3), 191-196.

Nakhleh, M. B. (1994). Chemical education research in the laboratory environment: How can research uncover what students are learning? *Journal of Chemical Education 71(3)*, 201-205.

Nakhleh, M.B., & Samarapungavan, A. (1999). Elementary school children's beliefs about matter. *Journal of Research in Science Teaching, 36*(7), 777-805.

National Committee on Science Education Standards and Assessment (1996). *National Science Education Standards.* Washington: National Research Council.

Nielsen, H. (1994). Seductive texts with serious intentions. *Educational Researcher, 24*(1), 4-12.

Nisbet, J. D., & Entwistle, N. (1970). *Educational Research Methods*. London: University of London Press.

Novak, J. D. (1976). Learning process and teaching methods. *Science Education, 60*(4), 493-521.

Novak, J. D. (1988). Learning of science and the science of learning. *Studies in Science Education, 15*, 77-101.

Nunnally, J. C. (1978). *Psychometric theory*. New York: McGraw-Hill.

Odom, A. L. (1995). Secondary & College Biology Students’ Misconceptions about Diffusion & Osmosis. *The American Biology Teacher* 57(7), 409-115

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*(1), 45-61.

Odom, A. L., & Kelly, P. V. (2000). Integrating concept mapping and the learning cycle to teach diffusion and osmosis to high school biology students . *Science Education, 85*, 615-635.

Oppenheim, A. N. (1992). *Questionnaire design*, *interviewing and attitude measurement*. London: Pinter Publishers Ltd.

Osborne, J. (1996). Beyond constructivism. *Science Education, 80*(1), 53-82.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education* 25(9), 1049-1079.

Osborne, R., & Wittrock, M. (1985). The general learning model and its implication for science education. *Studies in Science Education, 12*, 59-87.

Othman, J., Treagust, D. F., & Chandrasegaran, A. L. (2008). An investigation into the relationship between students' conceptions of the particulate nature of matter and the understanding of chemical bonding. *International Journal of Science Education, 30*(11), 1531-1550.

Pasl, A., Jalil, M., AbuSbeih, Z., Boujettif, M., & Barakat, R. (2009). Autonomy in science education: A practical approach in attitude shifting towards science learning. *Journal*. Retrieved November 15, 2010, from http://www.springerlink.com/content/46612513476knh34/

Paulus, G. M. & Treagust, D. F. (1991). Conceptual difficulties in electricity and magnetism. *Journal of Science and Mathematics Education in South East Asia,* 14(2), 47–53.

Peterson, R. F., Treagust, D. F., & Garnett, P. (1989). Development and application of a diagnostic instrument to evaluate grade 11 and 12 students' concepts of covalent bonding and structure following a course of instruction. *Journal of Research in Science Teaching,* 26, 301–314.

Piaget, J. (1977). The development of thought: Equilibration of cognitive structures. New York: Viking.

Pintrich, P. J., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change:The role of motivational beliefs and classroom contextual factor in the process of conceptual change. *Review of Educational Research 63*, 167-200.

Posner, G. J., Strice, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accomodation of a scientific conception: Towards a theory of conceptual change. *Science Education, 66*(2), 211-227.

Rop, C. J. (1999), Student perspectives on success in high school chemistry. Journal of Research in Science Teaching, 36: 221–237.

Power, C. N., & Banerjee, A. C. (1991). The development of modules for the teaching of chemical equilibrium. *International Journal of Science Education, 13*(3), 355-362

Radwan, M. I. (1991). Development of secondary schools biology curriculum in *advance of biotechnology*. Unpublished Ph.D Thesis, Ain Shams University, Egypt.

Renstrom, L., Anderson, B., & Merton, F. (1990). Student conceptions of matter. *Journal of Educational Psychology, 82(3),* 555-569.

Reif, F., & Larkin, J. H. (1991). Cognition in scientific and everyday domains: Comparison and learning implications. *Journal of Research in Science Teaching, 28*(9), 733-760.

Roth, W., & Roychoudhury, A. (1994). Physics students' epistemologies and views about knowing and learning. *Journal of Research in Science Teaching, 31*(1), 5-30.

Sadler, R. S. (1988). Formative assessment and the design of instructional systems. *Instructional Science, 18*(2), 119-144.

Salta, K. and Tzougraki, C. (2004), Attitudes towards chemistry among 11th grade students in high schools in Greece. Science Education, 88: 535–547.

Saudi, M. (1988). The attitude of future science teacher towards knowledge and teaching of science and its relationship with their satisfaction of the teaching career. Unpublished Education Research, Riyadh, Saudi Arabia.

Scharmann, L. C., & Harris, W. M. (1992). Teaching evolution: Understanding and applying the nature of science. *Journal of Research in Science Teaching, 29*(4), 375-388.

Shatat, A. (1989). Influence of school level and achievement in science in the development of scientific attitudes of the students of Jordan. Unpublished Thesis. Yarmouk University.

Singer, J. E., Wu, H.-K., & Tal, R. (2003). Students' understanding of the particulate nature of matter. *School Science and Mathematics, 103(1), 28 – 44.*

Slavin, R. E. (1984). *Research methods in education*: *A practical guide*. New Jersey Prentice-Hall, In Slavin, R. E. (1995). *Cooperative learning*. Boston: Allyn & Bacon.

Smith, J. A. (1995). Semi-structured interviewing and qualitative analysis. London: Stage Publications.

Stake, R. (2000). *Case studies (2nd ed.)*. Thousand Oaks, CA: Stage Publications.

Stern, G.G., Stein, M.I. & Bloom, B.S.(1956). *Methods in Personality Assessment*. Glencoe, Ill: Free Press.

Stavy, R. (1994). States of matter - pedagogical sequence and teaching strategies based on cognitive research. In P. J. Frensham, R. F. Gunstone & R. T. White (Eds.), *The content of science: A constructivist approach to its teaching and learning*. London: Falmer Press.

Taber, K. S. (1999). Ideas about ionisation energy: a diagnostic instrument. *School Science Review*. *81*(295), 97 – 104.

Taber, K. S. (2001). Building the structural concepts of chemistry: some considerations from educational research. *Chemical Education International, 2*(2), 123-158.

Tamir , P . (1971). An alternative approach to the construction of multiple-choice test items. *Journal of Biological Education*, 5 , 305-307.

Tan, K. C. D. (2000). Development and application of a diagnostic instrument to evaluate secondary students' conceptions of qualitative analysis. Unpublished Thesis, Curtin University, Perth.

Tan, D. K-C. & Treagust, D. F. (1999). Evaluating students’ understanding of chemical bonding. *School Science Review, 81*, 75–83.

Tan, D. K.C., Treagust, D. F., Goh, N-K. & Chia, L-S. (2002). Development and application of a two-tier multiple choice diagnostic instrument to assess high school students’ understanding of inorganic qualitative analysis. *Journal of Research in Science Teaching, 39*(4), 283–301.

Tan, D. K.C., Taber, K. S., Goh, N. K. & Chia, L-S. (2005). The ionisation energy diagnostic instrument: a two-tier multiple-choice instrument to determine high school students’ understanding of ionisation energy. *Chemical Education Research and Practice, 6*(4), 180–197.

Tarakci, M., Hatipoglu, S., Tekkaya, C., & Ozden M., Y. (1999). A Cross-Age Study Of High School Students’ Understanding Of Diffusion And Osmosis. *Hacettepe Universitesi Egitim Fakultesi Dergisi*, 15, 84-93.

Taylor, P.C., Gilmer, P. J., & Tobin, K. (2002). *Transforming undergraduate science* teaching: Social constructivist perspectives. New York: Peter Lang Publishing.

Tekkaya, C. (2003). Remediating high school students’ misconceptions concerning diffusion and osmosis through concept mapping and conceptual change text. *Research in Science & Technological Education*, 21(1), 5-10.

Treagust, D. F. (1986). Evaluating students' misconceptions by means of diagnostic multiple choice items. *Research in Science Education, 16*, 199-207.

Treagust, D. F. (1988). The development and use of diagnostic instruments to evaluate students’ misconceptions in science. *International Journal of Science Education, 10,* 159–169.

Treagust, D. F. (1995). Diagnostic assessment of students' science knowledge. In S. M Glynn & R. Duit (Eds.), Learning science in schools: Research reforming practice. (Vol. 1, pp. 327-346). Mahwah, NJ: Lawrence Erlbaum.

Treagust, D. F (2006). Conceptual change as a viable approach to understand student learning in science In K. Tobin (Ed.), *Teaching and learning science: A handbook* (pp. 25-32).Westport, CT: Praeger Publishers.

Treagust, D. F. (2006). Diagnostic assessment in science as a means to improving teaching,learning and retention.Retrieved June 3, 2007, from http://science.uniserve.edu.au/pubs/procs/2006/treagust.pdf

Treagust, D. F. & Chandrasegaran, A. L. (2007). The Taiwan national science concept learning study in an international perspective. *International Journal of Science Education, 29*(4), 391–404

Treagust, D., Chandrasegaran, A., Crowley, J., Yung, B., Cheong, I., & Othman, J. (2009). Evaluating students' understanding of kinetic particle theory concepts relating to the states of matter, changes of state and diffusion: A cross-national study. *International Journal of Science and Mathematics Education, 8*(1), 141-164.

Treagust, D. F. & K Chittleborough, G. (2001). Chemistry: A Matter of Understanding Representations In J. Brophy (Ed.), Subject-specific instructional methods and activities (Vol. 8, pp. 239-267)

Treagust, D. F., Duit, R., & Fraser, B. J. (1996). Overview: Research on students' preinstructional conceptions - the driving force for improving teaching and learning in science and mathematics. In D. F. Treagust, R. Duit & B. J. Fraser (Eds.), *Improving teaching and learning in science and mathematics* (pp. 79-93). New York: Teachers College Press.

Treagust, D. F., Jacobowitz, R., Gallagher, J.J. & Parker, J. (2001) Using assessment as a guide in teaching for understanding: A study of middle school science class learning about sound. *Science Education*, 85, 137–157

Treagust, D.F. & Mann, M. (2000, April-May). *An instrument to diagnose students'* conceptions of breathing, gas exchange and respiration. A paper presented at the annual meeting of the National Association for Research in Science Teaching.

Tsai, C.-C., & Chou, C. (2002). Diagnosing students' alternative conceptions in science. *Journal of Computer Assisted Learning 18*(2), 157-165.

Turney, B. L., & Robb,G.P. (1971). *Research in education: An introduction*. Hinsdale: Dryden Press.

Tyson, L., Treagust, D. F. & Bucat, R. B. (1999). The complexity of teaching and learning chemical equilibrium. *Journal of Chemical Education, 35*, 1031–1055.

Tyson, L. M., Venville, G. J., Harrison, A.G., & Treagust, D. F. (1997). A multidimensional framework for interpreting conceptual change events in the classroom. *Science Education, 81*(4), 387-404.

Tytler, R (2002). Teaching for understanding: Constructivist/conceptual change teaching approaches. *Australian Science Teachers' Journal,* 48(4), 30-35.

Valanides, N. (2000). Primary student teachers' understanding of the particulate nature of matter and its transformations during dissolving. *Chemistry Education: Research and Practice in Europe, 1*(2), 249-262

Venville, G. J., & Treagust, D. F. (1998). Exploring conceptual change in genetics using a multidimensional interpretive framework. *Journal of Research in Science teaching, 35*(9), 1031-1055.

Verma, G.K. & Beard,R.M. (1981).What is educational research? Perspectives on techniques. Gowen, Aldershot.

Wandersee, J. H., J. J. Mintzes & J. D. Novak. (1994). Learning: Research on alternative conceptions. In D. Gabel (Eds.), *Handbook of Research in Science Teaching and Learning* (pp. 177-210). National Science Teachers Association: MacMillan Publishing Company.

Wang, J-R. (2004). Development and validation of a two-tier instrument to examine understanding of internal transport in plants and the human circulatory system. *International Journal of Science and Mathematics Education, 2*, 131–157.

Wiersma, W. (1986). Research methods in education: An introduction Boston: Allyn and Bacon.

Wiggins, G. & McTighe, J (1998). Understanding by design. The association of supervision and curriculum development. Retrieved January 10, 2008 from http://facstaffwebs.umes.edu/wclarson/UbD-BkWardDesign.pdf

Wittrock, M. C. (1994). Generative science teaching. In P. J. Fensham, R. F. Gunstone & R. T. White (Eds.), *The content of science:A constructivist approach to its teaching and learning* (pp. 225-262). London: Falmer Press.

Wolf, R. M. (1988). Questionnaires in keeves, Educational Research, Methodology and Measurement, an International Handbook. Oxford, UK: Pergamon Press.

Unaldi, U. & M. Bilgi, (2008). Investigating the scientific literacy of university students concerning strengthened greenhouse effect /global climate change and ozone depletion. *World Applied Sciences Journal*. 3(5): 858 – 864. http://www.idosi.org/wasj/wasj3(5)/22.pdf

Yager, R.E., Tamir, P. & Kellerman, L. (1994). Success with STS in Life Science Classrooms, Grades 4-12. *The American Biology Teacher*, 56 (5), 268-272.

Yarroch, W. L. (1985). Student understanding of chemical equation balancing *Journal of Research in Science Teaching, 22*, 449-459.

Yeany, R. H., & Miller, A. P. (1983). Effects of diagnostic/remedial instruction on science learning: A meta analysis. *Journal of Research in Science Teaching, 20*(1), 19-26.

Yezierski, E. J., & Birk, J. P. (2006). Misconceptions about the particulate nature of matter. *Journal of Chemical Education, 83*(6), 954-960.

Yore, L. D. & Treagust, D. F. (2006). Current realities and future possibilities: Language and science literacy – empowering research and informing instruction, International Journal of Science Education, 28(2), 291 –314.

Yu, S., (2005) Assessing student understanding of key ecological concepts. Graduate Institute of Science Education. National Taichung Teacher College. Taiwan, R.O.C.

Zuckerman, J. T. (1993). *Accurate and inaccurate conceptions about osmosis that accompanied meaningful problem solving*. Paper presented at the National Association for Research in Science Teaching annual meeting. Atlanta, GA.

APPENDICES

PERMISSION LETTER

(Translation from Arabic; see p. 156)

Dear pre-service science teacher:

I have been a science teacher for five years at Al-Russ Teacher's College. Currently, I am a full-time doctoral student at the Science & Mathematics Education Centre in Curtin University of Technology, Perth, Australia and I am investigating pre-service teacher students understanding of the diffusion and osmosis and the particulate nature of matter aspects of the national science curriculum as well as pre-service teachers attitude to science.

One main objective is to find out how teaching and learning of diffusion and osmosis and the particulate nature of matter living environment topics can be improved. To meet this objective, I am conducting a research project on the topic and will be collecting 200 surveys from pre-service science teachers from 15 teaching institutes.

With your permission, I would like to ask you to participate in this research project. You will be asked to complete a two-part assessment relating to the diffusion and osmosis and the particulate nature of matter as well as investigating your attitude towards science. None of your selections will impact upon your grades. It is expected that completing the items will take approximately 45 minutes.

The purpose of this letter is to introduce you to this research project and to inform you that participation is completely voluntary. You may decide not to participate and there will be no penalty for this.

Thank you.

Yours truly,

____

I have read and understand the contents of this letter:

____

(Block letters)

____

(Date)

____

(Signature)

PERMISSION LETTER (ARABIC)

عزيزي طالب العلوم :

عملت معيدا بقسم المناهج وطرق التدريس (طرق تدريس علوم) لمدة خمس سنوات في كلية الرس للمعلمين. حاليا ، أنا طالب في جامعة كيرتن باستراليا في مرحلة الدكتوراه في قسم مركز العلوم والرياضيات التعليمي .

وتهدف الدراسة إلى لقياس مدى فهم الطلاب لمفهوم الخاصية الاسموزية والانتشار وطبيعة تحرك الجسيمات والقسم الثاني من الدراسة هو معرفة مدى ميول الطلاب نحو العلوم.
والعدد المطلوب لهذه الدراسة ما يقارب 200 طالب من 15 كلية للمعلمين أن أمكن.

أتمنى مشاركتك في هذا المشروع البحثي. والمطلوب استكمال الإجابة على هذا الجزئيين من البحث. ومن المتوقع أن يستغرق حوالي 45 دقيقة.
الغرض من هذه المقدمة هو أعطائك فكرة عن الباحث والبحث ونتائجه التي سيكون لها دور أن شاء الله في المشاركة بتطوير عملية التدريس، وأحيطك علما بأن مشاركتك تطوعية . قد تقرر عدم الاستمرار في أي وقت ولن تكون هناك عقوبة على ذلك وكذلك أجابتك لن يكون لها تأثير في درجاتك أو معدلك الدراسي ولن يطلع على هذه الإجابات الا الباحث.

شكرا لك .

تفضلوا بقبول فائق الاحترام،

____

لقد قرأت وفهمت مضمون هذا الطلب :

____
(الاسم اختياري)

____
(التاريخ)

____
(التوقيع)

DIFFUSION, OSMOSIS AND PARTICLE THEORY (DOPT) TWO-TIER DIAGNOSTIC INSTRUMENT

l. 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

The reason for my answer is because:

1. The lack of a membrane means that osmosis and diffusion cannot occur.
2. There is movement of particles between regions of different concentrations.
3. The dye separates into small particles and mixes with water.

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

a. high to low concentrations

b. low to high concentrations

The reason for my answer is because:

1. There are too many particles crowded into one area; therefore, they move to an area; with more room.
2. Particles in areas of greater concentration are more likely to bounce toward other areas.
3. The particles tend to move until the two areas are isotonic, and then the particles stop moving.

3. A glucose solution can be made more concentrated by:

a. adding more water

b. adding more glucose

The reason for my answer is because:

1. The more water there is, the more glucose it will take to saturate the solution.

2. Concentration means the dissolving of something.

3. It increases the number of dissolved particles.

4. 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

The reason for my answer is because:

1. There is movement of particles from a high to low concentration.

2. The sugar is heavier than water and will sink.

3. There will be more time for settling.

5. 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

The reason for my answer is because:

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

2. If the dye molecules stopped, they would settle to the bottom of the container.

3. Molecules are always moving.

6. 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 (see Figure 1). Which beaker became light green first?

a. Beaker 1

b. Beaker 2

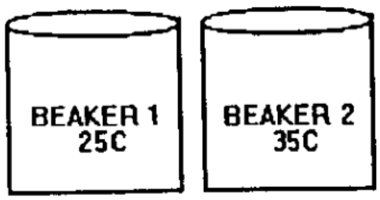


Figure A1.

The reason for my answer is because:

1. The lower temperature breaks down the dye.
2. The dye molecules move faster at higher temperatures.
3. The cold temperature speeds up the molecules.

7. Figure 4 is a picture of a plant cell that lives in freshwater. If this cell were placed in a beaker of 25% saltwater solution, the central vacuole would:

a. increase in size

b. decrease in size

c. remain the same size

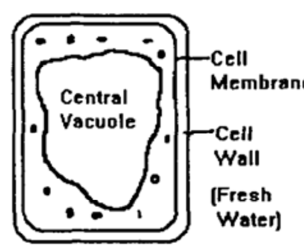


Figure A4.

The reason for my answer is because:

1. Salt absorbs the water from the central vacuole.
2. Water will move from the vacuole to the saltwater solution.
3. Salt solution outside the cell cannot affect the vacuole inside the cell.

8. All cell membranes are:

a. semipermeable

b. permeable

The reason for my answer is because:

1. They allow some substances to pass.
2. The membrane requires nutrients to live.
3. They allow ALL nutrients to pass.

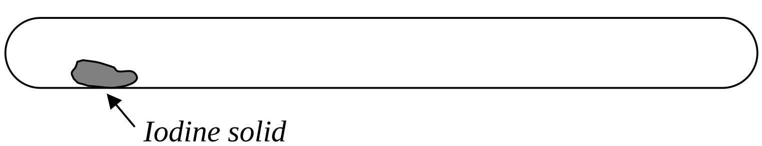
9. Assume a beaker of pure water has been boiling for 30 minutes. What is/are in the bubbles in the boiling water?

A. Oxygen gas and hydrogen gas
B. Water vapour (water in the gaseous state)
C. Heat

Reason:

1. The hydrogen and oxygen atoms in water molecules break away from each other to form gases.
2. Heat energy is absorbed by the water and released as bubbles.
3. The forces between the water molecules are overcome, and the water molecules break free from the liquid to form steam.

10. 1.0g sample of solid iodine is placed in a tube and the tube is sealed after all of the air is removed. The total mass of the tube and the solid iodine is 27.0g.



The tube is then heated until all of the iodine evaporates and the tube is filled with iodine gas. The mass after heating will be

A. less than 27.0g

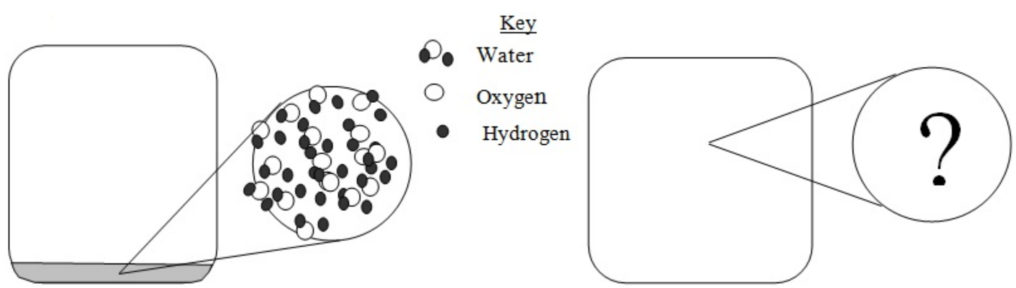
B. 27.0g

C. more than 27.0g

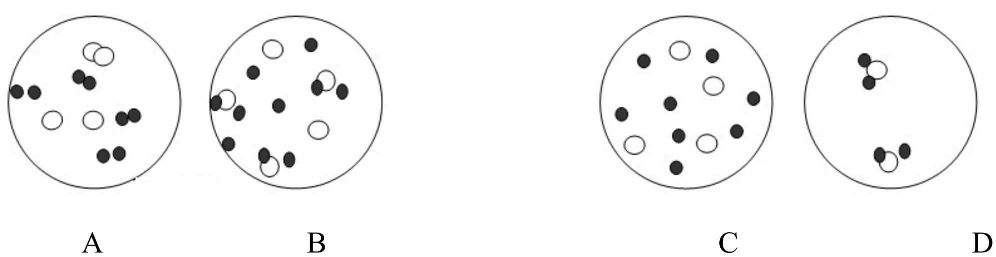
Reason

1. A gas weighs less than a solid.
2. Mass is conserved.
3. The particles become more spread out when the iodine becomes a gas.

11. The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.



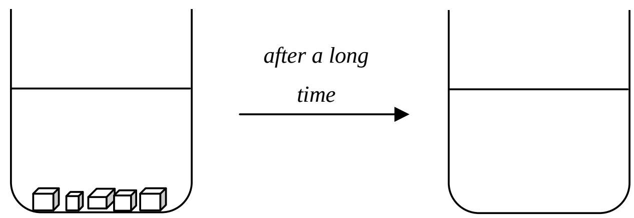
What would the magnified view show after the water evaporates?



Reason:

1. Water molecules have escaped into the air.
2. Water molecules have decomposed into oxygen and hydrogen gas.
3. Water molecules have spread further apart.
4. A mixture of water molecules, oxygen atoms and hydrogen atoms are produced

12. Crystals of sugar are placed in a beaker of water. If the mixture is left to stand long enough, the sugar crystals eventually can no longer be seen, and the water will taste sweet.



(A) True (B) False

Reason

1. The sugar molecules gain heat from the surrounding and melt, forming a liquid. This liquid mixes with the water.
3. Water molecules surround sugar molecules on the surfaces of the crystals and pull them away from the crystal lattice.
4. The sugar crystals will only dissolve when stirred. Stirring causes the sugar crystals to break up into smaller particles that will then spread in the water and can no longer be seen.

13. A sample of solid sulphur has the following properties:

(I) brittle,

(II) melting point 113^{o} C.

Which, if any, of the above properties would be the same for one single atom of sulphur obtained from the sample?

A. I and II

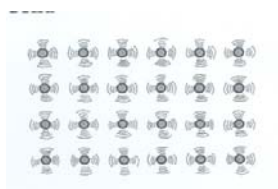
B. I only

C. None of the properties.

Reason

1. An atom is the smallest particle of an element that has the same properties as the element.
2. A sulphur atom has smooth faces and sharp edges and so breaks easily when a force is applied.
3. The properties of an element are a result of the interactions of its individual particles.

14. Which of the following diagrams correctly represents the particles in a solid like copper?

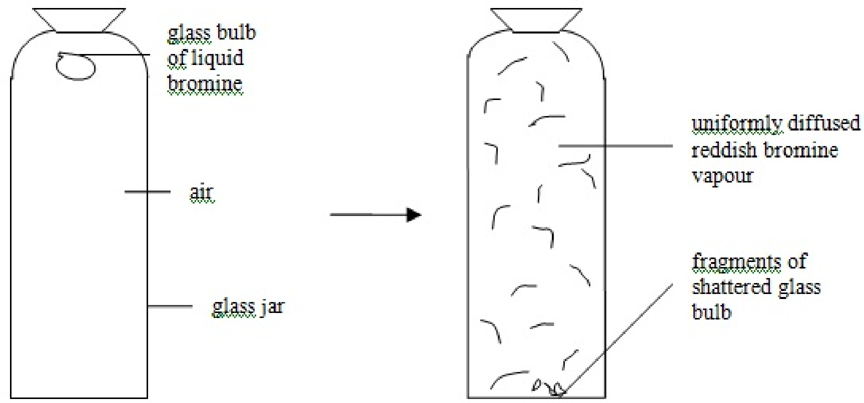
A  B  C 

The reason for my choice of answer is:

1 The particles are closely packed in a regular pattern.
2 The particles are closely packed together.
3 The particles are closely packed and vibrate about fixed positions.
4 The particles are held together by strong attractive forces.

15. A small glass bulb containing liquid bromine was dropped into a tall jar of air and the jar was immediately stoppered. The bulb shattered on hitting the bottom of the jar, releasing bromine vapour. After several hours, reddish bromine vapour had diffused uniformly throughout the jar.

If the experiment is repeated after pumping out most of the air from the jar, we would expect the reddish bromine vapour to diffuse and fill the jar within a few seconds.

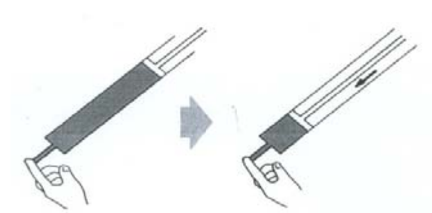


A True B False

The reason for my choice of answer is:

1 Bromine diffuses faster because fewer collisions occur between bromine and air particles.
2 The heavier bromine molecules will sink to the bottom of the jar.
3 Bromine molecules can now occupy the extra space that was previously taken up by the air particles.
4 Bromine molecules diffuse slowly in a random zigzag manner to fill the jar.

16**.** The diagram shows a pump containing a fixed mass of a coloured gas that is compressed by pushing the plunger down.



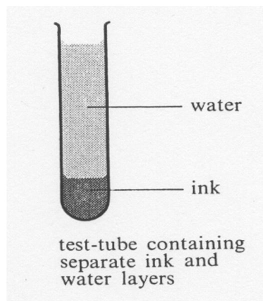
We can conclude that

A the volume and mass of air in the pump have decreased.
B the volume of air has decreased while the mass has increased.
C the volume of air has decreased while the mass remains constant.

The reason for my choice of answer is:

1 The gas particles have been pushed closer together because they are widely spaced.
2 Gas particles can be readily compressed and pushed closer together.
3 The number of air particles has decreased.

17**.** A small amount of blue ink was carefully placed at the bottom of a test-tube containing some water as shown in the diagram.



After several days, the ink would have diffused throughout the water producing a uniformly blue solution.

A True B False

The reason for my choice of answer is:

1 The particles of ink are in constant random motion.
2 The heavier ink particles sink to the bottom of the test-tube.
3 Ink particles readily dissolve in water.
4 The ink particles diffuse from a region of higher concentration to lower concentration.

ARABIC VERSION OF DOPT DIAGNOSTIC INSTRUMENT

(pp. 167-175)

ضع دائرة حول الإجابة الصحيحة.إذا أردت تغيير أجابتك ضع علامة (x) على الإجابة الخاطئة ثم اختار إجابة أخرى

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1 . لنفترض بوجود كوب كبير ملئ بالماء الصافي و بإضافة قطرة من صبغة زرقاء إلى كوب الماء. في نهاية الأمر سيؤدي ذلك إلى تحول الماء إلي أزرق خفيف اللون.
عملية تحول الصبغة الزرقاء لتصبح موزعة في الماء هي :

A .تناضح (الخاصية الاسموزية)
B .انتشار
C .ردة فعل بين الماء والصبغة

وسبب جوابي هو (اختار سبب واحد) :

1. عدم وجود الغشاء يعني الانتشار و الخاصية الاسموزية لا يمكن أن تحدث.
2. هناك حركة للجسيمات بين المجالات ذات التركيزات المختلفة.
3. تنفصل الصبغة إلى جسيمات صغيرة وتختلط مع الماء.

2. أثناء عملية انتشار الصبغة بالماء ، سوف تتحرك الجسيمات :

A. من التركيزات العالية إلى المنخفضة
B. من التركيزات المنخفضة إلى عالية

والسبب هو:

1. هناك عدد كبير جدا من الجزيئات تزدحم في مجال واحد ، لذلك فهي تتحرك إلى مجال ما وتكون تجمعات وترسبات متعددة .
2. الجسيمات في مجالات التركيز الأكبر على الأرجح يتم طردها للانتقال إلى مجالات آخري.
3. الجزيئات تميل إلى التحرك حتى تصل إلى مجالين متساويين التوتر ، وبعد ذلك تتوقف حركه الجزيئات.

3. يمكن زيادة تركيز محلول الجلوكوز(سكر) عند :

A. إضافة المزيد من الماء
B. إضافة المزيد من الجلوكوز

والسبب هو:

1. المزيد من الماء ، يجعل الجلوكوز يكون محلولا مشبعا.
2. التركيز يعنى إذابة شئ ماء.
3 .التركيز يعنى زيادة عدد الجزيئات المذابة.

4.إذا أضيفت كمية صغيرة من السكر إلى كوب ماء. ماهى حالة جزيئات السكر إذا تركت لفترة طويلة من الزمن دون تحريك :

A. جزيئات السكر أكثر تركيزا في الجزء السفلي في الكوب
B .توزع بالتساوي في جميع أنحاء الكوب

والسبب هو :

1.هناك حركة للجسيمات من المجلات عالية التركيزالى منخفضة التركيز .
2 .السكر أثقل من الماء وسوف يستقر في الأسفل.
3. سيكون هناك المزيد من الوقت لترسب السكر.

5. لنفترض انك أضفت قطرة من الصبغة الزرقاء إلى كوب ماء وبعد عدة ساعات يصبح لون الماء بالكوب ازرق فاتح. في هذا الوقت ، جزيئات الصبغ سوف:

A. تتوقف عن التحرك
B. مواصلة التحرك بشكل عشوائي

والسبب هو:

1. شكل اللون بالكوب يكون متماثلا.أما إذا تحركت جزيئات الصبغة يصبح لون الكوب غير متماثل.
2. إذا توقفت جزيئات الصبغة، سوف تستقر في أسفل الكوب.
3. الجزيئات في حركه دائمة.

6. لنفترض أن هناك كوبان كبيران بهما كميات متساوية من المياه الصافية مع اختلاف درجات الحرارة. ،بعد ذلك أضيفت صبغة خضراء لكل منهما. في اى كوب يتلون الماء بالصبغة أسرع من الآخر:

A. كوب 1
B. كوب2

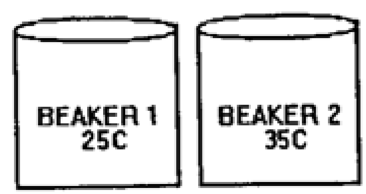


Figure A1.

. **والسبب هو :**

1. انخفاض درجة الحرارة يقلل انتشار الصبغة.
2. جزيئات الصبغة تتحرك بسرعة اكبر في ارتفاع درجات الحرارة.
3 . درجة الحرارة الباردة تعمل على تسريع حركة الجزيئات.

7. في الشكل 4 صورة لخلية نباتية تعيش في مياه عذبة. وإذا وضعنا هذه الخلية في كوب من المياه المالحة بتركيز 25 ٪...... مركز تجويف الخلية في هذه الحالة سوف :

A. يزداد حجمه
B. ينخفض حجمه
C. يبقى نفس الحجم

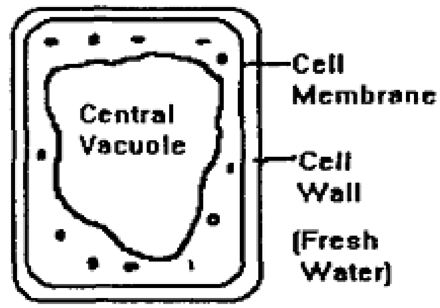


Figure A4.

والسبب هو :

1. الملح يمتص الماء من فجوة الخلية.
2. المياه تنتقل من فجوة الخلية إلى محلول الملح.
3. محلول الملح خارج الخلية لا يمكن أن يؤثر على الفجوة داخل الخلية.

8. جميع أغشيه الخلايا هي :

A. شبه نافذة
B. نافذة

والسبب هو :

1. الخلايا تسمح لبعض المواد بالمرور.
2. الغشاء يحتاج للمواد المغذية ليعيش .
3. الأغشية تسمح لجميع العناصر المغذية بالمرور.

9. نفترض أن كوب من الماء النقي وتم غليانه لمدة 30 دقيقة كما هو بالشكل أدناه. ما هي هذه الفقاعات التي ظهرت بالماء المغلي؟

1. غاز الأكسجين وغاز الهيدروجين
2. بخار الماء (الماء في حالة غازية)
3 . حرارة

السبب هو:

1. ذرات الهيدروجين والأوكسجين في جزيئات الماء تخلصت من بعضها البعض لتكون غازات.
2. أمتص الماء الطاقة الحرارية وأخرجها على شكل فقاعات.
3. القوى بين جزيئات الماء تم التغلب عليها ، وبالتالي جزيئات الماء تفككت وأصبح شكلها من سائل إلى بخار.

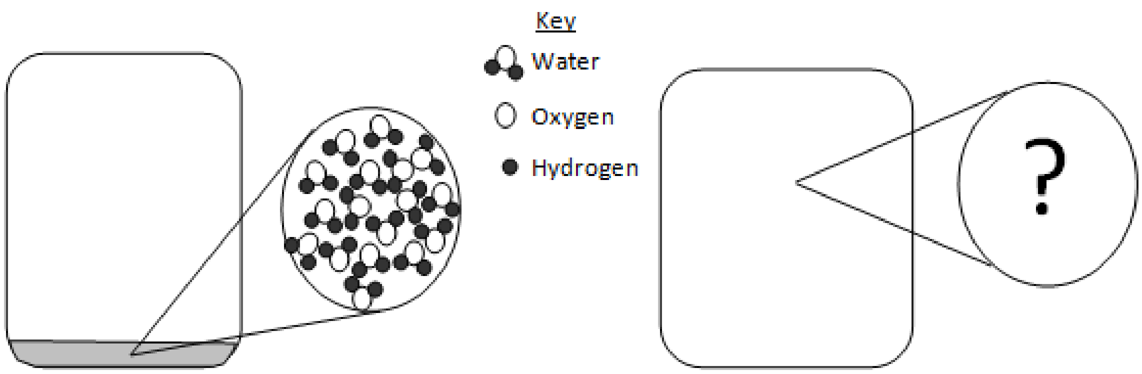
10. 1.0 جرام عينة من اليود الصلب وضعت في أنبوبه بعد أن فرغت من الهواء وتم إغلاقها. الكتلة الاجماليه للانبوبه واليود الصلب هي 27 جرام .

سخنت الانبوبه بعد ذلك إلى أن تبخراليود وأصبحت الانبوبه مملوءة بغاز اليود.
ماهي الكتلة الجديدة للانبوبه بعد التسخين؟

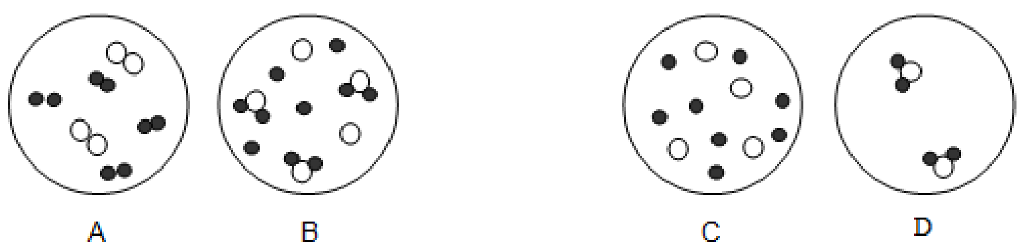
A. اقل من 27 جرام
B. 27 جرام
C. أكثر من 27 جرام

والسبب هو:
1. الغاز يزن أقل من المادة الصلبة.
2. أن الكتلة محافظ عليها.
3. الجزيئات أصبحت أكثر انتشارا عندما كان اليود غازا.

11. الدائرة على اليسار توضح شكل جزيء من الماء عندما ننظر إليه تحت المجهر

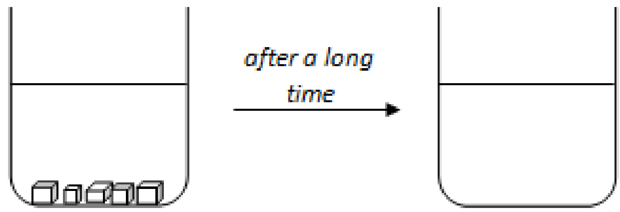


ماهو الشكل المتوقع تحت المجهر بعد تبخر الماء؟



والسبب هو :
1. جزيئات الماء تفرقت في الهواء.
2. جزيئات الماء تحللت إلى غاز الأوكسجين وغاز الهيدروجين.
3. جزيئات الماء أصبحت أجزاء متباعدة عن بعضها البعض.
4. خليط من جزيئات الماء ، وذرات الأكسجين وذرات الهيدروجين تم إنتاجها

12. قطعه من السكر وضعت في كوب ماء وترك الخليط لمده كافية. في النهاية. لايمكننا مشاهدة قطعة السكر وطعم الماء يصبح حلوا.



A. هذه العبارة صحيحة
B. غير صحيحة

والسبب هو:

1. جزيئات السكر اكتسبت الحرارة من الماء المحيط بها وذابت ، وتحولت إلى سائل. هذا السائل اختلط مع الماء.
2. أحاطت جزيئات الماء جزيئات السكر على سطح قطعت السكر وجذبتها بعيدا عن شكلها السابق كقطعه مشبكه.
3. قطعة السكر لاتذوب إلا عندما يتم تحريكها. لان تحريك قطعة السكر يسبب تفتته إلى جسيمات صغيره وعندها تنتشر بالماء ولايمكن مشاهدتها.

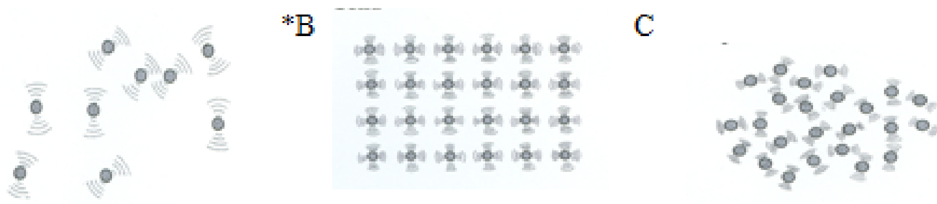
13. عينة من الكبريت الصلب لديها الخصائص التالية :
(I) هشة
(I I) نقطة انصهارها 113 درجة .

من هذه العينة أخذنا ذره كبريت واحده. أي من الخصائص المذكورة أعلاه تكون موجودة في ذرة الكبريت الواحدة ؟
A. الخاصية الأولى والثانية.
B. الخاصية الأولى فقط
C . لاتوجد أي خاصية مما ذكر.

والسبب هو:

1. الذرة هي أصغر الجسيمات الموجودة بالعناصر و لها نفس الخصائص كما العنصر.
2. ذرة الكبريت لديها سطح ناعم وحواف حادة وتنكسر بسهولة عندما يضغط عليها بقوة.
3. خصائص عنصر من عناصر هي نتيجة لتفاعلات الجزيئات كل على حده.

14. أي من الرسوم البيانية التالية يمثل بشكل صحيح جزيئات النحاس الصلبة؟



والسبب هو:

1 . الجزيئات ترتبط ارتباطا وثيقا كحزمة في نموذج منتظم.

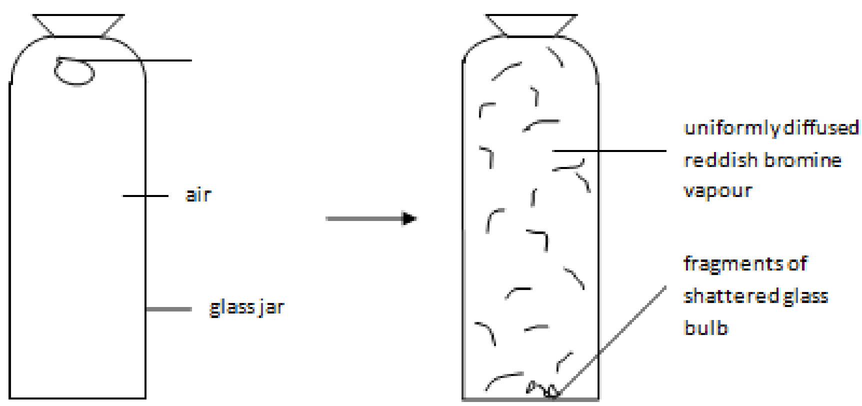
2 . الجزيئات حزم متقاربة مع بعضها.

4 .الجزيئات حزم متقاربة تتذبذب للوصول معا لموضع ثابت.

5 . الجزيئات متبثه مع بعض بسبب قوة جاذبيه كبيره .

15. لمبة زجاجيه صغيرة تحتوي على سائل البروم أسقطت في جره مملوء بالهواء ، وأغلقت الجرة بسرعة. اللمبة انكسرت وسقطت في الجزء السفلي من الجرة ، وبعد عدة ساعات ، بخار البروم المحمر ينتشر بشكل مطرد في جميع إنحاء الجرة.

وإذا تم تكرار التجربة بعد سحب الجزء الأكبر من الهواء من الجرة ، نتوقع من بخار البروم أن ينتشر ويملئ الجرة في غضون بضع ثوان.



A. صح **B. خطأ**

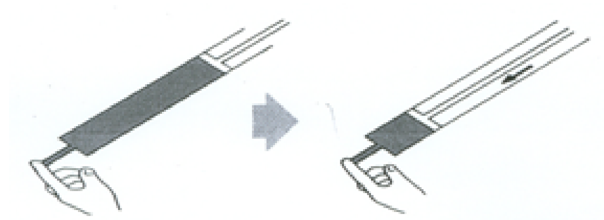
والسبب هو :

1 . البروم ينتشر أسرع لان التصادم بين جزيئات الهواء والبروم يكون أقل.

2 . جزيئات البروم الأثقل سوف تستقر في قاع الجرة.

3 . جزيئات البروم يمكن أن تشغل الآن الجزء الأكبر والتي كانت من قبل مملئه بجزيئات الهواء.
4 . جزيئات البروم تنتشر ببطء و بطريقة عشوائية متحرجة لملء الجرة.

16. يبين الرسم البياني مضخة تحتوي على كتلة ثابتة من غاز ملون والذي يتم ضغطه بواسطة المكبس.



يمكنك أن تلخص ما يحدث:
A . حجم وكتلة الهواء في المضخة قد انخفضت.
B . حجم الهواء انخفض في حين أن الكتلة قد ازدادت.
C .حجم الهواء انخفض في حين أن الكتلة بقيت ثابتة.

والسبب هو :
1. جزيئات الغاز دفعت لبعضها البعض لأنها كانت متباعدة على نطاق واسع.
2 .جزيئات الغاز يمكن بسهولة ضغطها ودفعها لبعضها البعض.
3 .عدد جزيئات الهواء قد انخفض.

TEST OF SCIENCE-RELATED ATTITUDES (TOSRA)

Barry J. Fraser

DIRECTION

1 This test contains a number of statements about science. You will be asked what you yourself think about these statements. There are no 'right' or 'wrong' answers. Your opinion is what is wanted.

2 All answers should be given on the separate Answer Sheet. Please do not write on this booklet.

3 For each statement, draw a circle around
SA if you **STRONGLY AGREE** with the statement;
A if you **AGREE** with the statement:
N if you are **NOT SURE**;
D if you **DISAGREE** with the statement:
SD if you **STRONGLY DISAGREE** with the statement.

Practice Item

0 It would be interesting to learn about boats. Suppose that you **AGREE** with this statement, then you would circle **A** on your Answer Sheet.

SA A N D SD

4 If you change your mind about an answer, cross it out and circle another one.

5 Although some statements in this test are fairly similar to other statements, you are asked to indicate your opinion about all statements.

1 I would prefer to find out why something happens by doing an experiment than by being told.

2 I enjoy reading about things which disagree with my previous ideas.

3 Science lessons are fun.

4 Doing experiments is not as good as finding out information from teachers.

5 I dislike repeating experiments to check that I get the same results.

6 I dislike science lessons.

7 I would prefer to do experiments than to read about them.

8 I am curious about the world in which we live.

9 School should have more science lessons each week.

10 I would rather agree with other people than do an experiment to find out for myself.

11 Finding out about new things is unimportant.

12 Science lessons bore me.

13 I would prefer to do my own experiments than to find out information from a teacher.

14 I like to listen to people whose opinions are different from mine.

15 Science is one of the most interesting school subjects.

16 I would rather find out about things by asking an expert than by doing an experiment.

17 I find it boring to hear about new ideas.

18 Science lessons are a waste of time.

19 I would rather solve a problem by doing an experiment than be told the answer.

20 In science experiments, I like to use new methods which I have not used before.

21 I really enjoy going to science lessons.

22 It is better to ask the teacher the answer than to find it out by doing experiments.

23 I am unwilling to change my ideas when evidence shows that the ideas are poor.

24 The material covered in science lessons is uninteresting.

25 I would prefer to do an experiment on a topic than to read about it in science magazines.

26 In science experiments, I report unexpected results as well as expected ones.

27 I look forward to science lessons.

28 It is better to be told scientific facts than to find them out from experiments.

29 I dislike listening to other people's opinions.

30 I would enjoy school more if there were no science lessons.

Attitude to Scientific Inquiry

1 I would prefer to find out why something happens by doing an experiment than by being told.

2 Doing experiments is not as good as finding out information from teachers.

3 I would prefer to do experiments than to read about them.

4 I would rather agree with other people than do an experiment to find out for myself.

5 I would prefer to do my own experiments than to find out information from a teacher.

6 I would rather find out about things by asking an expert than by doing an experiment.

7 I would rather solve a problem by doing an experiment than be told the answer.

8 It is better to ask the teacher the answer than to find it out by doing experiments.

9 I would prefer to do an experiment on a topic than to read about it in science magazines.

10 It is better to be told scientific facts than to find them out from experiments.

Adoption of Scientific Attitudes

1 I enjoy reading about things which disagree with my previous ideas.

2 I dislike repeating experiments to check that I get the same results.

3 I am curious about the world in which we live.

4 Finding out about new things is unimportant.

5 I like to listen to people whose opinions are different from mine.

6 I find it boring to hear about new ideas.

7 In science experiments, I like to use new methods which I have not used before.

8 I am unwilling to change my ideas when evidence shows that the ideas are poor.

9 In science experiments, I report unexpected results as well as expected ones.

10 I dislike listening to other people's opinions.

Enjoyment of Science Lessons

1 Science lessons are fun.

2 I dislike science lessons.

3 School should have more science lessons each week.

4 Science lessons bore me.

5 Science is one of the most interesting school subjects.

6 Science lessons are a waste of time.

7 I really enjoy going to science lessons.

8 The material covered in science lessons is uninteresting.

9 I look forward to science lessons.

10 I would enjoy school more if there were no science lessons.

Test of Science-Related Attitudes

Answer Sheet

Name ______________________________

School ____________________ Year/Class ____________

Page 2	STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE	Page 3	STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE	Page 4	STRONGLY AGREE	AGREE	NOT SURE	DISAGREE	STRONGLY DISAGREE
1	SA	A	N	D	SD	29	SA	A	N	D	SD	50	SA	A	N	D	SD
2	SA	A	N	D	SD	30	SA	A	N	D	SD	51	SA	A	N	D	SD
3	SA	A	N	D	SD	31	SA	A	N	D	SD	52	SA	A	N	D	SD
4	SA	A	N	D	SD	32	SA	A	N	D	SD	53	SA	A	N	D	SD
5	SA	A	N	D	SD	33	SA	A	N	D	SD	54	SA	A	N	D	SD
6	SA	A	N	D	SD	34	SA	A	N	D	SD	55	SA	A	N	D	SD
7	SA	A	N	D	SD	35	SA	A	N	D	SD	56	SA	A	N	D	SD
8	SA	A	N	D	SD	36	SA	A	N	D	SD	57	SA	A	N	D	SD
9	SA	A	N	D	SD	37	SA	A	N	D	SD	58	SA	A	N	D	SD
10	SA	A	N	D	SD	38	SA	A	N	D	SD	59	SA	A	N	D	SD
11	SA	A	N	D	SD	39	SA	A	N	D	SD	60	SA	A	N	D	SD
12	SA	A	N	D	SD	40	SA	A	N	D	SD	61	SA	A	N	D	SD
13	SA	A	N	D	SD	41	SA	A	N	D	SD	62	SA	A	N	D	SD
14	SA	A	N	D	SD	42	SA	A	N	D	SD	63	SA	A	N	D	SD
15	SA	A	N	D	SD	43	SA	A	N	D	SD	64	SA	A	N	D	SD
16	SA	A	N	D	SD	44	SA	A	N	D	SD	65	SA	A	N	D	SD
17	SA	A	N	D	SD	45	SA	A	N	D	SD	66	SA	A	N	D	SD
18	SA	A	N	D	SD	46	SA	A	N	D	SD	67	SA	A	N	D	SD
19	SA	A	N	D	SD	47	SA	A	N	D	SD	68	SA	A	N	D	SD
20	SA	A	N	D	SD	48	SA	A	N	D	SD	69	SA	A	N	D	SD
21	SA	A	N	D	SD	49	SA	A	N	D	SD	70	SA	A	N	D	SD
22	SA	A	N	D	SD												
23	SA	A	N	D	SD												
24	SA	A	N	D	SD												
25	SA	A	N	D	SD												
26	SA	A	N	D	SD												
27	SA	A	N	D	SD												
28	SA	A	N	D	SD												

For Teacher Use Only

S ___ N ___ I ___ A ___ E ___ L ___ C ___

I Attitude to Scientific Inquiry	A Adoption of Scientific Attitudes	E Enjoyment of Science Lessons
1 (+)	2 (+)	3 (+)
4 (-)	5 (-)	6 (-)
7 (+)	8 (+)	9 (+)
10 (-)	11 (-)	12 (-)
13 (+)	14 (+)	15 (+)
16 (-)	17 (-)	18 (-)
19 (+)	20 (+)	21(+)
22 (-)	23 (-)	24 (-)
25 (+)	26 (+)	27 (+)
28 (-)	29 (-)	30 (-)

For positive items (+), responses SA, A, N, D, SD are scored 5, 4,3,2,1, respectively. For negative items (-), responses SA, A, N, D, SD, are scored 1, 2, 3, 4, 5, respectively. Omitted or invalid responses are scored 3.

ARABIC VERSION OF TOSRA QUESTIONNAIRE

(pp. 183-186)

ضع دائرة حول الاتجاه الذي يمثل رأيك .إذا ارت تغير إجابتك ضع علامة (خطأ) واختر إجابة آخري

أفضل أن اعرف لماذا تحدث الأشياء نتيجة لعمل تجربة أكثر من مجرد أن اخبر بها

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

أنا استمتع بقراءة الأشياء التي لا توافق أفكاري السابقة

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق بشده

تعتبر دروس العلوم ممتعة

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق بشده

الحصول على المعلومة من قبل المعلم أفضل من الحصول عليها من إجراء تجربة

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

لا أحب إعادة إجراء التجربة للتأكد من النتائج

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

لا أحب دروس العلوم

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

أفضل إجراء التجارب أكثر من القراءة عنها

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

أنا فضولي لمعرفة العالم الذي نعيش فيه

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

ينبغي للمدرسة أن تزيد من حصص العلوم الأسبوعية

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

أنا أميل إلى الموافقة مع بعض الناس للحصول على ما أريد أكثر من أن اجري تجربة لذلك

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

اكتشاف أشياء جديدة ليس ذو أهمية

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

حصص العلوم مملة بالنسبة لي

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

أفضل أن احصل على المعلومة عن طريق عمل تجربة أكثر من أن احصل عليها عن طريق المعلم

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

ارغب بالاستماع للأشخاص اللذين اختلف معهم بالأفكار

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

يعتبر العلوم من أمتع الحصص الدراسية

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

أفضل إيجاد الأشياء عن طريق سؤال شخص آخر قام بعمل التجربة أكثر من أن اعمل التجربة بنفسي

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

الاستماع للأشياء الجديدة ممل بالنسبة لي

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

تعتبر حصص العلوم مضيعة للوقت

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

أفضل حل المشكلة عن طريق إجراء تجربة أكثر من مجرد إيجاد الإجابة من شخص ما

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

في تجارب العلوم أفضل استخدام طرق جديدة لم تستخدم من قبل

موافق بشدة   موافق   غير متأكد   غير موافق   غير موافق

أنا حقا استمتع بحضور حصص العلوم

موافق بشدة　　موافق　　غير متأكد　　غير موافق　　غير موافق

سؤال المعلم للحصول على الإجابة أفضل من الحصول عليها عن طريق عمل تجربة

موافق بشدة　　موافق　　غير متأكد　　غير موافق　　غير موافق

أنا لست على استعداد أن أغير أفكاري عندما تثبت الأدلة بأنها ضعيفة

موافق بشدة　　موافق　　غير متأكد　　غير موافق　　غير موافق

المواد التي تتناولها دروس العلوم ليست ممتعة

موافق بشدة　　موافق　　غير متأكد　　غير موافق　　غير موافق

أفضل أن أقوم بتجربة عن موضوع ما أكثر من أن أقراء عنه في مجلة علمية

موافق بشدة　　موافق　　غير متأكد　　غير موافق　　غير موافق

في التجارب العلمية تقوم التقارير بذكر نتائج متوقعة وغير متوقعة على حد سواء

موافق بشدة　　موافق　　غير متأكد　　غير موافق　　غير موافق

دائما ما أكون متطلع لدروس العلوم

موافق بشدة　　موافق　　غير متأكد　　غير موافق　　غير موافق

إخبارك عن الحقائق العلمية أفضل من استنتاجها عن طريق تجربة

موافق بشدة　　موافق　　غير متأكد　　غير موافق　　غير موافق

لا أحب الاستماع لآراء أخرى

موافق بشدة　　موافق　　غير متأكد　　غير موافق　　غير موافق

استمتع بالذهاب للمدرسة أكثر إذا لم يكن فيها حصص علوم

موافق بشدة　　موافق　　غير متأكد　　غير موافق　　غير موافق

شكرا لك أخي الطالب وأتمنى لك التوفيق