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The effect of learning styles and attitude on preservice elementary teachers' conceptual understanding of chemistry and the nature of matter in a simulation-based learning environment

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THE EFFECT OF LEARNING STYLES AND ATTITUDE ON PRESERVICE ELEMENTARY TEACHERS' CONCEPTUAL UNDERSTANDING OF CHEMISTRY AND THE NATURE OF MATTER IN A SIMULATION-BASED LEARNING ENVIRONMENT

A Dissertation

Submitted

in Partial Fulfillment

of the Requirements for the Degree

Doctor of Education

Approved:

Dr. Robert M. Boody, Committee Chair

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December 2009

DEDICATION

I dedicate this dissertation to the very important people to me on Earth. First of these were my father, Hablan, and my deceased mother, Zahrah Kakka, who went to the other World unexpectedly in a tragic accident at a young age. These are the people who risked their lives and sacrificed everything in their power to raise and educate me in the best way possible. I also dedicate this project to all family members especially my grandmother Fahima whom I am blessed with her prayers; my uncle Abdelhadi Kasim, who was a great soccer player; my cousin Abdulla Kakka, a school principal, an English teacher, and a great soccer player who also died tragically at a young age. Also, I give special dedication to my all beloved sisters and brothers, especially Amira for her great support and encouragement. Finally, to my true friends and soccer teammates who always wished me the best in my education, and who would love to see me back among them.

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ABSTRACT

This causal-comparative descriptive study investigated the achievement of pre-service elementary teachers taking an introductory physical science course that integrates inquiry-based instruction with computer simulations. The study was intended to explore if pre-service elementary teachers with different attitudes towards science as well as students with different learning styles would benefit differentially.

Four research questions including four hypotheses were developed. The first major question consist of four specific hypothesis that addressed preservice elementary teachers' learning styles (Active/Reflective, Sensing/Intuitive, Visual/Verbal, and Sequential/Global) and their conceptual understanding of chemistry and the particulate nature of matter in a science class which use hands-on learning integrated with computer based simulated activities. The second major question pertained to the relationship between preservice teachers learning science and chemistry and their attitude towards science. The third major question related to preservice elementary teachers science and chemistry achievement gain scores and attitude average affected by their learning styles. Finally, the fourth question pertained to the dissipation or the minimization of preservice elementary teachers' science and chemistry misconceptions over the course of study.

Three instruments were given to perservice elementary teachers in three different classes: pretest/posttest for the science conceptual understanding examination, and pretest-only for the science attitude and learning styles instruments. Total usable science attitude surveys returned was 67 out of 70. The overall average mean was 3.13 (SD = .51) on a five point scale. Total return of science achievement instrument was 65, with a total

mean test score (quantitative and qualitative together) of 6.38 (SD = 3.05) on the pretest, with a post test mean of 9.06 (SD = 4.19).

Results revealed no statistically significant achievement gain scores based on students' learning styles, entering in all 4-combined dimensions at the same time Visual/Verbal, Sensing/Intuitive, Sequential/Global, and Active/Reflective ($p > .05$), indicating the four learning styles dimensions cannot be used to predict students' achievement gain. Results also indicated that there was no significant relationship between achievement gain and students' attitude ($p > .05$). Attitude and learning style together were also not significantly related to achievement gain.

Preservice elementary teachers' comprehension of chemical concepts in this study varied from no comprehension to fair comprehension, and included many misconceptions; no answer showed complete understanding of the concepts. Many of the preservice teachers held misconception related to evaporation. If not addressed in science content and methods courses, this could be a problem as this new generation of teachers goes out to teach.

It is proposed that to fix preservice elementary teachers' conceptual problems, curriculum needs to specifically focus on misconceptions. The preservice elementary subjects of the study showed a variety of misconceptions on both pretest and posttest concerning the particulate and the kinetic nature of matter. Suggestions are made is that a science content course could more contribute to preservice students' conceptual change if curriculum designers incorporate a segment that specifically addresses misconceptions, especially those misconceptions that have been documented in the literature for decades.

A robust cognitive model for science education is proposed to increase teachers' science knowledge and to decrease science misconceptions.

CHAPTER 1

INTRODUCTION

In this technological era, science plays a big role in our lives. Learning and understanding aspects of science has become a priority because it is part of our daily activities. People engage in science conversations at home, in public and in schools. To keep up with the worlds' pace, one has to be scientifically literate. By doing so, people learn how to think and make decisions creatively. To acquire such skills, one has to understand science and the process of science (National Science Education Standards, [NSES], 1996). Many have recently addressed the importance of having scientifically literate citizens to satisfy the US demand and compete globally (e.g., NSES, 1996; National Research Council [NRC], 2007).

Beginning to learn science at an early age helps learners view the world scientifically (NRC, 1993). Learners would grow up holding facts and scientific beliefs as they continue to a higher level of education. Perhaps learners would be able to investigate and examine different issues they encounter in life based on the science ideas they have learned previously. To help this happen, elementary teachers should have a positive influence on their students in learning science. However, in elementary schools science is often taught by an unspecialized teacher or "a generalist teacher" (Appleton, 2007, p. 495). This might lead elementary science teachers to avoid science or teach science inadequately.

Appleton noted that the tendency of elementary teachers to avoid science has not changed in twenty years (Appleton, 2007). Why do elementary teachers avoid teaching science? They have limited science subject matter knowledge, limited science pedagogical content knowledge, and low confidence in teaching science (Appleton, 2007, p. 497). Harlen (1997) explained strategies used by such teachers to avoid science, such as:

> 1. Avoidance—teaching as little of the subject as possible;
> 2. Keeping to topics where confidence is greater—usually meaning more biology than physical science;
> 3. Stressing process outcomes rather than conceptual development outcomes;
> 4. Relying on the book, or prescriptive work cards which give pupils step-by-step instructions;
> 5. Emphasizing expository teaching and underplaying questioning and discussion; and
> 6. Avoiding all but the simplest practical work and any equipment that can go wrong. (p. 335)

Such strategies can lead teachers to think that there are no difficulties in teaching science while in fact these ways of teaching can hinder science learning. Science teachers influence their students (Loughran, 2007). Therefore, elementary science teachers may mislead students if teachers' understanding is flawed. Unqualified teachers don't have enough background to give students what they need to construct their knowledge, especially when teachers pass on their flawed science conceptions (Loughran, 2007, p. 1045). Students cannot learn well unless their teachers have learned well. As a result, students start to encounter conceptual problems and eventually misconceptions evolve and will be difficult to address.

Many students at the elementary through college level hold misconceptions related to science (Novick & Nussbaum, 1981; Osborne & Cosgrove, 1983). Several studies have found that students hold ideas about science that do not match scientific facts, and these were found to be resistant to ordinary classroom teaching (Stavy, 1991). Some of the misconceptions students bring are contingent upon the interaction with their teachers in the classroom (Gilbert & Zylberstajn, 1985). In a 1994 review of research on alternative conceptions, it was found that the teachers in the 1980s "often subscribe to the same alternative conceptions as their students" (Wandersee, Mintzes, & Novak, 1994, p. 189). Hence, students tend to replicate what teachers do in the science classroom.

The current state of pre-service elementary teachers' knowledge is inadequate. Studies which examine elementary and secondary teachers' subject matter knowledge of life, physics science concepts, chemistry, earth and space science continues to the present date (Abell, 2007). Several studies examined teachers' science concept understanding, finding mixed results. Hope and Townsend (1983), for instance, have found positive results for New Zealand elementary teachers in biology concepts but not in physics concepts (force, friction, gravity). Hope and Townsend (1983) also have acknowledged that some misconceptions about basic concepts occur at a lower level of education before students enter high school; therefore, primary school teachers can be held responsible for students' action. Ameh and Gunstone, on the other hand, examined pre-service science secondary teachers in Australia and Nigeria and found results of misconceptions in both life and physical science (cited in Abell, 2007). It is essential to recognize the depth of this problem and take the appropriate measures to solve it. This problem can be improved by using newer approaches to teaching pre-service elementary science teachers.

Improving student learning in science should be a priority for elementary schools. One researcher in science education, regarding current school practice, stated: "Our institutions of formal education do not help most students to learn science with understanding" (C. W. Anderson, 2007, p. 5). He added that most students and adults in schools are not achieving a reasonable definition of scientific literacy (C. W. Anderson, 2007).

Learning science is also addressed in conceptual change research, which focuses on restructuring learners' flawed conceptual understanding to acquire science concepts that are accepted by the field (Duit & Treagust, 2003). Snir, Smith, and Raz (2002) noted regarding this issue in the article "Linking Phenomena with Competing Underlying Models: A Software Tool for Introducing Students to the Particulate Model of Matter":

> The particulate model of matter is one of the central ideas in modern science. It is also a central subject in the middle and high school science curriculum. Yet, as is well known, this topic is very hard for students to learn and internalize. We believe that understanding the particulate model of matter is difficult because it requires that students develop an understanding of two profoundly important, but counterintuitive, ideas. The first one is the idea of the discontinuity of matter and the second is the idea of an explanatory model as a metaconcept in science. (p. 795)

The National Commission on Mathematics and Science Teaching for the 21st Century, (Glenn, 2000) declared that

> U.S. Children are losing the ability to respond not just to the challenges already presented by the 21st century but to its potential as well. We are

> failing to capture the interest of our youth for scientific and mathematical ideas. We are not instructing them to the level of competence they will need to live their lives and work at their jobs productively. Perhaps worst of all, we are not challenging their imaginations deeply enough. (p. 4)

The report continued that

> We are of one mind in our belief that the way to interest children in mathematics and science is through teachers who are not only enthusiastic about their subjects, but who are also steeped in their disciplines and who have the professional training-as teachers-to teach those subjects well. (p. 5)

The picture has become clear that in order to educate students in science, science teachers must have accurate conceptual scientific knowledge. This is, however, not the case with some pre-service science teachers.

Pre-service science teachers' knowledge of their subject matter is crucial in the learning process (Haidar, 1997). Teachers are an important key to the success or failure of students (Mitchener & Anderson, 1989). The literature shows considerable evidence that pre-service science teachers lack understanding of science, and that they often interpret science phenomena unscientifically. In other words, they have the naïve ideas or misconceptions that their students have (Atwood & Atwood, 1996; Bendall, Goldberg & Galili, 1993; Gabel, Samuel & Hunn, 1987; Haidar, 1997). Pre-service teachers' conceptions of subject matter and pedagogy have potential influence on classroom practice (Lederman, Newsome, & Latz, 1994). They too often are underprepared, lack confidence, and lack the ability to interest children in learning science (Glenn, 2000). To help students understand the science content with less ambiguity, pre-service teachers need to master learning science and master teaching it in their classrooms.

Simply put, many pre-service science teachers do not posses good science knowledge; hence, they fall into science misconceptions. This is a problem that must be addressed using different approaches to teaching pre-service teachers. These approaches could include the use of technology, such as a simulation-based classroom environment, that should ease learning of abstract science concepts.

Since science involves dealing with abstract concepts, more of these science misconceptions will evolve in the pre-service teachers' explanations to science phenomena. However, with the help of hands-on lab activities and the use of computer simulations, pre-service teachers would create a better understanding of science concepts. Studies have shown that students who use computer based activities do better than those who learn through traditional methods (Hakerem, Dobrynina, & Shore, 1993). Simulations ease the situation when it comes to abstract concepts or subjects that are hard to see by the naked eye such as molecules, atoms, ions and so forth. Thus, simulations help in learning science by increase students' conceptual understanding (Zacharia & Anderson, 2003).

Multimedia has an effect on students learning environments. It can create wider opportunities to explore, aid in retention of information learned, and increase retrieval information stored in the student's memory. Simulation, for instance, has been used widely in the field of education and science education. Especially in science teaching methods are transitioning from the real world to the virtual world (e.g. simulations) for a variety of reasons. Computers have been used in teaching science and its effect on students who go through active-engagement have shown better results than those who went through traditional instruction (Hakerem, Dobrynina, & Shore, 1993).

Educational simulation provides learning of real world activities through interaction with a computer. According to Alessi and Trollip (2001), simulation is defined as a model of some phenomenon or activity in which students interact with multi dimensional activity using a computer. Many studies have shown the usefulness of computer simulation in science education (Rieber & Parmley, 1995). In the chemistry field for instance, learners can perform a titration experiment and obtain measurements for calculating the strength of acids and bases. The simulation in such an experiment allows learners to interact and communicate actively with the program (Martinez-Jimenez, Pontes-Pedrajas, Polo, & Climent-Bellido, 2003). Also the learner can have access to all kinds of information such as texts, images of different types of data and graphics in the computer while working on the simulated experiment.

In the simulation programs, the simulation offers more than merely replicating an activity. It simplifies the activity by omitting or changing variables, or adding details or features (Alessi & Trollip, 2001). Learners come to understand the characteristics of a given phenomenon and how to deal with it and control it in any situation. The control of action helps the learner build a mental image of the procedure. In return, learners can have the opportunities to explore more about the phenomena, and test it by doing more practice and improve the way of learning.

By using computer simulations in a science class, pre-service teachers should be able to see the unseen particles as a reality before their eyes. The best science education combines the body of knowledge with hands-on activities of scientific work (Flick & Bell, 2000). Hence, the use of the hands-on activities would give students the ability to touch the tools that they otherwise cannot do with simulations alone.

Some students have less interest in science and science career due to their negative attitude towards science (Osborne, Simon & Collins, 2003) and lower self assurance (Harlen, 1997). Because students have different learning techniques or styles, different backgrounds, strengths and weakness, levels of interests and motivations towards learning (Felder & Brent, 2005), pre-service teachers will likely learn somewhat differently.

Learning styles are seen as "the preference or predisposition of an individual to perceive and process information in a particular way or combination of ways" (Sarasin, 1998, p.3). Understanding students' learning styles may well be a help in raising students' conceptual understanding in science education. In fact, it is not only important for students' understanding of a subject matter and how they can learn best, but can also help instructors and curriculum designers to articulate approaches and strategies for students with different learning styles (Felder, 1993; Sarasin, 1998). According to Avitabile (1998), multimedia methods enhance students' learning. He added that multimedia methods are more effective for students with certain learning styles, such as sensing and cognitive.

Statement of the Problem

A persistent problem in American Public Education is that preservice elementary teachers' science knowledge is inadequate. This is particularly true because elementary school science is often taught by a generalist teacher with limited science content knowledge and low confidence and enthusiasm about teaching science. This can lead to failing to capture students' interest in science at a young age and giving a flawed knowledge base to work from. Thus, the question becomes, how can we help prepare teachers better?

Simulations, were students interact with the dynamic computer environment, have proven their worth in science classroom (Rieber, Smith, Al-Ghafry, Strickland, Chu, & Spahi, 1996; Steinberg, 2000). Computer-based simulations eases and simplifies the subject matter, reduces challenges for student learning, and helps student develop their own conceptual understanding of the subject matter (Powell & Lord, 1998). So using simulations in preparing presrvice elementary teachers in science seems like a good idea. However, there are reasons to believe that the use of simulations can work differently based on independent factors such as students' attitude towards science and their learning styles. This study was developed to explore this issue.

Research Questions

The primary questions being addressed in this research are as follows:

1. Does learning style affect pre-service elementary teachers' conceptual understanding of the particulate nature of matter in a science class which uses hands-on learning integrated with computer based simulated activities?

Specific Hypotheses:

a. Active learners would exhibit greater conceptual understanding of the particulate nature of matter than reflective learners.

b. Sensing learners would exhibit greater conceptual understanding of the particulate nature of matter than intuitive learners.

c. Visual learners would exhibit greater conceptual understanding of the particulate nature of matter than verbal learners.

d. Sequential learners would exhibit greater conceptual understanding of the particulate nature of matter than global learners.

2. Is pre-service elementary majors' science learning in a course using hands-on learning integrated with computer-based simulations related to their attitude towards science? "

3. Is pre-service elementary teachers' achievement gain scores affected by attitude and learning styles?

4. Were preservice elementary science teachers' science misconceptions dissipated over the course of this study?

Significance of the Study

"Traditional 'chalk & talk' lecture does not accommodate all types of learners" (Zywno, 2002, p. 3). Researchers indicate that different learning styles can lead students to engage in the learning process differently (Felder, 1996). The use of hands-on experiments and the use of simulations may help pre-service teachers understand a science concept with fewer ambiguities and reduce naïve concepts or misconceptions. Pre-service teachers might consider simulations relevant to their learning styles, and feel that simulations are an appropriate replacement for more traditional methods such as lectures.

Pre-service science teachers can apply their cognitive styles that allow them to perceive information in different ways at different rates (Felder, 1993). This approach would enhance pre-service elementary students' conceptual understanding that would allow them to have a positive attitude towards science teaching strategies. This approach would also help curriculum designers to articulate approaches and strategies for pre-service elementary teachers with different learning styles. This would create a culture of pre-service teachers who are competent in establishing the elementary students' science foundation.

The idea of having a qualified pre-service teacher for the job is to plant the seeds for new generations to come. It seems reasonable that children will develop a more positive attitude towards science if they have qualified science teachers. In order to achieve elementary student success in learning science preservice elementary teachers should be interested in science, learn science accurately, and be enthusiastic about it. The National Commission on Mathematics and Science Teaching for the 21st Century has stated "we are of one mind in our belief that the way to interest children in mathematics and science is through teachers who are not only enthusiastic about their subjects, but who are also steeped in their disciplines and who have the professional training--as teachers--to teach those subjects well" (Glenn, 2000, p. 5). It is clear that pre-service elementary teachers are key factors in developing a society that is capable of functioning well with high performance in science applications.

CHAPTER 2

REVIEW OF LITERATURE

"Science teaching in the primary grades has been a persistent problem…" (Schibeci & Hickey, 2000, p. 1154). Pre-service elementary teachers will interact with students soon after they graduate. The attitude and success of students towards science may depend on their science teachers' attitude and success. Therefore, pre-service teachers' scientific knowledge and competency to teach science concepts are critical to elementary students to advance in their education.

This literature review chapter focuses on the research questions to be addressed in this study. The questions are: (a) does learning style affect pre-service elementary teachers' conceptual understanding of the particulate nature of matter in a science class which use hands-on learning integrated with computer based simulated activities?, (b) is pre-service elementary majors' science learning in a course using hands-on learning integrated with computer-based simulations related to their attitude towards science?, (c) is pre-service elementary teachers' achievement gain scores affected by attitude average and by their learning styles? and (d) were pre-service elementary science teachers' misconceptions dissipated over the course of this study? To support all these questions, this chapter includes four major sections: (a) science teaching, (b) attitude towards science, (c) simulation technology, and (d) learning styles.

Science Teaching

Conceptual Understanding of Basics in Science

"After 15 years of focused standards-based reform, improvements in U.S. science education are modest at best" (NRC, 2007). Major challenges of scientific issues facing the U.S. such as cloning, climate change, and alternative fuels have a great impact on producing scientifically educated citizens for the future (NRC, 2007). Recent reports have shown the importance of science education in elementary schools for the U.S. to lead the world in science (Fulp, 2002). Results of the spring 2007 5th grade California Standards Test (CST) in Science indicate that 37% of California students and 46% of Bay Area students scored proficient (California Department of Education, 2007). It was found among the reasons attributed to Bay Area students' not performing well that the current status of science education is weak due to inconsistency and poor quality (Dorph, Goldstein, Lee, Lepori, Schneider, & Venkatesan, 2007).

The National Commission on Mathematics and Science Teaching report suggests that success depends not only on how we educate our students in general, "but on how well we educate them in mathematics and science specifically" (Glenn, 2000, p. 4). The report continued to say "our children are falling behind: they are simply not world-class learners when it comes to mathematics and science" (p. 4), and the "current preparation that students in the United States receive in mathematics and science is... unacceptable" (p. 7).

At the elementary level, science classes present some form of chemistry or particulate nature of matter concepts such as atoms and molecules that require some basic imagination and thinking. Elementary students must know about properties of matter including changes of state and effect of temperature on different substances. It is essential to acknowledge that teaching atomic and molecular theory in the early grades is not an easy task due to the small size of particles and the astronomical numbers of invisible atoms involved (AAAS, 1993). Atoms cannot be directly observed. However, students must learn about the basics of the atomic theory in variety of different ways gradually starting at a low grade level. The American Association for the Advancement of Science (1993) provides more detailed picture on how elementary students progress in learning science. Students at kindergarten through grade 2 should be taught about concepts such as mixing, heating, freezing, dissolving, bending, and exposing things to light in order to respond to change in materials and encouraged to describe what they did. Students at grades 3 through 5 should be able to design and build materials with different properties, write descriptions of their experiments, and perhaps present findings in tables and graphs using computer technologies. Hence, students should able to describe more complex properties such as conducting heat and electricity, buoyancy, response to magnets, solubility, and inspect materials composed of large particles (e.g., salt, sugar, powder) using magnifiers, and (c) students grades 6 through 8 should get acquainted with matter with some understanding to molecules and atoms, though it is an abstract concept. It also reasonable for students at this level understands the general idea of phenomena of matter that can be explicated by its essential microscopic particles, atoms and molecules. Tables 1, 2 and 3 demonstrate each of the three elementary stages that students should know at the end of each grade according to the online current version of AAAS (1993).

Table 1

Students Learning Stages at the End of 2nd Grade

Objects can be described in terms of their properties. Some properties, such as hardness and flexibility, depend upon what material the object is made of, and some properties, such as size and shape, do not.

Things can be done to materials to change some of their properties, but not all materials respond the same way to what is done to them.

To help students learn such concepts it is reasonable to start at lower grades in order for them to retain scientific knowledge for the future. This leads to the need for qualified and proficient elementary science teachers who have pedagogical knowledge and have a good attitude towards teaching science (Appleton, 2007).

Table 2

Students Learning Stages at the End of 5th Grade

Heating and cooling can cause changes in the properties of materials, but not all materials respond the same way to being heated and cooled.

Many kinds of changes occur faster under hotter conditions.

No matter how parts of an object are assembled, the weight of the whole object is always the same as the sum of the parts; and when an object is broken into parts, the parts have the same total weight as the original object.

Materials may be composed of parts that are too small to be seen without magnification.

When a new material is made by combining two or more materials, it has properties that are different from the original materials.

A lot of different materials can be made from a small number of basic kinds of materials.

All materials have certain physical properties, such as strength, hardness, flexibility, durability, resistance to water and fire, and ease of conducting heat.

Collections of pieces (powders, marbles, sugar cubes, or wooden blocks) may have properties that the individual pieces do not.

Substances may move from place to place, but they never appear out of nowhere and never just disappear.

Table 3

Students Learning Stages at the End of 8th Grade

All matter is made up of atoms, which are far too small to see directly through a microscope.
The atoms of any element are like other atoms of the same element, but are different from the atoms of other elements.
Atoms may link together in well-defined molecules, or may be packed together in crystal patterns. Different arrangements of atoms into groups compose all substances and determine the characteristic properties of substances.
Equal volumes of different materials usually have different masses.
Atoms and molecules are perpetually in motion. Increased temperature means greater average energy of motion, so most substances expand when heated.
In solids, the atoms or molecules are closely locked in position and can only vibrate. In liquids, they have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another except during occasional collisions.
The temperature and acidity of a solution influence reaction rates. Many substances dissolve in water, which may greatly facilitate reactions between them.
Chemical elements are those substances that do not break down during normal laboratory reactions involving such treatments as heating, exposure to electric current, or reaction with acids. All substances from living and nonliving things can be broken down to a set of about 100 elements, but since most elements tend to combine with others, few elements are found in their pure form.

(table continues)

There are groups of elements that have similar properties, including highly reactive metals, less-reactive metals, highly reactive nonmetals (such as chlorine, fluorine, and oxygen), and some almost completely nonreactive gases (such as helium and neon).

An important kind of reaction between substances involves the combination of oxygen with something else—as in burning or rusting.

Carbon and hydrogen are common elements of living matter.

No matter how substances within a closed system interact with one another, or how they combine or break apart, the total mass of the system remains the same.

The idea of atoms explains the conservation of matter: If the number of atoms stays the same no matter how the same atoms are rearranged, then their total mass stays the same.

Materials vary in how they respond to electric currents, magnetic forces, and visible light or other electromagnetic waves.

A substance has characteristic properties such as density, a boiling point, and solubility, all of which are independent of the amount of the substance and can be used to identify it. (NRC, 1996)

Substances react chemically in characteristic ways with other substances to form new substances with different characteristic properties. (NRC, 1996)

If samples of both the original substances and the final substances involved in a chemical reaction are broken down, they are found to be made up of the same set of elements.

The idea of atoms explains chemical reactions: When substances interact to form new substances, the atoms that make up the molecules of the original substances combine in new ways.

The need is for proficient science teachers to do their job well to enable our children to be successful in science. Pre-service science teachers' scientific knowledge and ability to apply it in the teaching process successfully is essential. If applied properly, this knowledge can improve student understanding of the subject matter; not applied properly, it can inhibit student understanding of science (Anderson & Mitchner, 1994; Mitchener & Anderson, 1989). Thus, teachers can have either a positive or negative effect on students learning (Mitchener & Anderson, 1989; Tobin, Tippins & Gallard, 1994).

Negative effects on students learning may arise from the lack of pre-service science teachers able to teach science in most of the schools in the United States. The Glenn Commission report *Before it's too Late*, released in 2000, described the current situation of science teachers' skills as incompetent: (a) "...more than one in five high school science teachers lack even a minor in their main teaching field" (p. 19), and (b) "twelve percent of all new hires enter the classroom without any formal training" (p. 19). Furthermore, in some areas, at the high school level the chances of students getting a licensed science and mathematics teachers who holds a degree in science is less than 50% (Glenn, 2000). Teaching science to elementary students in the United States needs to be elevated to a higher level (Weiss, 1994, 1997). A 1993 survey shows that teachers do not feel well-prepared to teach science; only 28 percent said they are very well-qualified to teach life science, and less than 10 percent reported being very well-qualified in physical science (Weiss, 1997). Many elementary pre-service science teachers admit that it is difficult to teach science due to their impoverished understanding of scientific concepts

(Weiss, 1994), and that they tend to recycle or repeat what they have been taught (Luera & Otto, 2005). The way they teach science is not far from the traditional teacher centered science teaching method: a combination of listening to the teacher and taking notes, including much memorization of vocabulary and facts (Stefanich, 1992).

In order to teach science concepts more adequately, science teachers must first understand science concepts appropriately (Abd-El-Khalick & Lederman, 2000). They also have to understand the nature of science and link it to science teaching to help students learn the concepts (Hodson, 1988). Teachers' conceptions of the nature of science may transfer during teaching in classrooms (Lederman, 1992). This could have dire consequences on students' understanding of science if teachers are not adequately prepared to teaching science concepts regarding particulate nature of matter (PNM) to elementary students and beyond. In this case, children's understanding of the conservation of matter, for instance, may be altered.

Piaget studied children's perception and was able to acknowledge preexisting knowledge in children (BouJaoude, 1991). The study of Piaget and Inhelder in 1974 included a First Stage, which features reliance on instant understanding, and therefore, students do not respond to deductive reasoning. The non-conservation of substance, weight and volume, or the complete disappearance of the sugar that students at age 12 believe, showed their failure to utilize logical reasoning. Students did not conceive of the continued existence of sugar, or comprehend the change in weight of the water, once the sugar had dissolved within water. The only effect students conceive at this stage upon sugar dissolving in water is that it makes the water taste sugary. It was further observed during the study that the students trusted their visual understanding which may have led to a distorted comprehension of the water and sugar phenomenon. Although Piaget and Inhelder established that students' reasoning is guided by perceptual experience and have no interest in pursuing a logical reasoning, Stavy 1990, found that children pre-existing knowledge may contribute to their misconceptions about dissolving. Lack of understanding by students may have created alternative framework of the water and sugar phenomenon.

Students' alternative conceptions arise when students' ideas do not resemble those of the scientific community (Nakhleh, 1992; Schmidt, 1995). These alternative conceptions, also known as student misconceptions, may come from the lack of basic knowledge, prior knowledge or from the way these students were taught (Gilbert & Watts, 1983; Shuell, 1987). Other labels that researchers use for student misconceptions about science concepts include children's science (Gilbert, Osborne, & Fensham, 1982), alternative framework (Driver, 1981), spontaneous reasoning (Viennot, 1979), and naïve conceptions (Champagne, Gunstone, & Klopfer, 1983). Naïve conceptions were first identified in physics, mechanics, and other abstract concepts such as light, heat, and electricity (Reiner, Slotta, Chi, & Resnick, 2000). Misconceptions are not mistakes that can easily be recognized by students (Schmidt, 1995). Students who carry misconceptions or alternative conceptions face difficulties learning new concepts because their old concepts are so deeply instilled in their learning foundations that makes it difficult for them to accept a new one (Schoon & Boone, 1998). Students enter into classrooms with firmly held beliefs and conceptions that are resistant to change (Reiner, Slotta, Chi & Resnick, 2000). Students bring to science class their own strong views on how and why things work in their surroundings (Osborn & Cosgrove, 1983).

Student's Misconceptions in Science and Chemistry

The literature has an abundance of studies that point out misconceptions that students have regarding different scientific concepts. In physics, researchers have talked about alternative frameworks for temperature and heat, electrical circuits, and light (Anderson, 1986). Similarly, many other researchers have talked about student's conceptions (Anderson, 1990; Abraham, Grzybowski, Renner, & Marek, 1992; BouJaoude, 1991; Gabel, 1999; Hewson & Hewson, 1989; Lee, Eichinger, C.W. Anderson, Berkheimer, & Blakeslee, 1993; Marek, 1986; Novick & Nussbaum 1981; Osborne & Cosgrove, 1983; Shymansky et al., 1993; Stavy, 1990; Shepherd & Renner, 1982).

Science educators have realized that learning science has not been an easy task for many students. Many students do not understand fundamental science ideas and eventually develop ill-formed concepts, or misconceptions (Gabel, 1999; Gabel, Samuel & Hunn, 1987). For example, understanding density is a challenge to many science students. One misconception that has been found among students is equating density with weight, e.g. when compressing aluminum cans, they should weigh more because compressed cans are denser (Stepans, Beiswenger, & Dyche, 1986). Osborne and Cosgrove (1983) have studied children's misconceptions about phenomena related to water, and found that children have ideas about the changes of state of water that differ from current scientific perspectives. In 1991, Bodner studied Osborne and Cosgrove's work on the changes of states of water, and asked graduate students in chemistry the following question: "Assume that a beaker of water on a hot plate has been boiling for an hour. Within the liquid, bubbles can be seen rising to the surface. What are the bubbles made of?" (p. 385). He found that more than 70% of the graduate students answered that the bubbles contain water vapor, steam, or molecules of water; 20% suggested that the bubbles are made up of air or oxygen; and 5% said it was a mixture of hydrogen and oxygen gas. Although older students have taken more science classes and been exposed to more science teaching, they often still hold similar ideas about science that elementary students do (Osborn & Cosgrove, 1983). Ironically, in the same study of boiling water, (e.g. "what are the bubbles made of"), the 15-year-old students held more nonscientific ideas than the 12 years old students. Their answer to the question was "water changed into oxygen and hydrogen on boiling" (Osborn & Cosgrove, 1983, p. 836).

In some cases students follow patterns different from those that are taught in the learned curriculum, which is the amount of student's learning in a subject, skills, attitudes, cognitive abilities, and understanding the nature of science (Larson, 1995). Larson stressed the different patterns of learning that some students adapt in their science classroom, namely the hidden curriculum. The discovery was called Fatima's rules, which was named after the student Fatima who created ways that allowed her to pass a chemistry without putting in much work. Some of the students in her chemistry class were influenced by such rules, and seem to have attempted the completion of their chemistry assignments for the purpose of high grades and not necessarily to understand the material. Furthermore, they called their teacher as soon as they faced any minor difficulty. Also, they did not read all the materials for the chemistry class, instead they focussed on certain points, such as bolded words, charts, questions and answers at the end of the book, and copied lab work from the group to achieve their first goal of getting the highest grades. Some students paid less attention because they worked in groups and because the teacher generally trusted their work so they did not feel the discomfort of the abstract chemistry class. Fatima's strategy of passing science or chemistry class with minimal understanding of science concepts coupled with the teaching strategies that science teachers use to avoid science provided by Harlen (1997) would make a potent recipe for creating a culture of elementary science teachers that lack full and effective content knowledge. Thus, the results could be manifested in the elementary students constructing naive science concepts.

Traditional vs. Inquiry Methods in Teaching Science

In traditional methods for teaching science a lecture-based classroom is standard. While the teacher is the center of the learning process, the students passively listen, or write what was said or written on the board (Hake, 1998). Hake noted that "traditional passive-student introductory physics courses, even those delivered by the most talented and popular instructors, imparted little conceptual understanding of Newtonian mechanics" (p. 64). In traditional methods for teaching science students lack the versatile use of scientific means such as concept mapping because teachers depend only on simple ways of teaching (Rice, Ryan, Samson, 1998). For instance, elementary science teaching instruction tends to be limited to reading textbooks, memorizing words and facts, listening to the teacher and, perhaps, filling out worksheets (Stefanich, 1992; Weiss, 1994). According to Weiss (1997), "traditional lecture/textbook methodologies" is the core of science instruction (p. 3).

In some cases, hands-on activities and laboratory work exist, but are very limited in many science classrooms. According to Weiss (1997), the time allotted to lecture and discussion in a science classroom in elementary, middle, and high school science classes is 38%, as compared to 23% for hands-on/laboratory work. The National Science Education Standards (1996) address the inquiry and hands-on laboratory work, and emphasize science curricula that allow students to be the center of the learning environment. The National Research Council (NRC, 1996; R. D. Anderson, 2007) acknowledge science curricula that emphasize the use of an inquiry-based approach. Scientific inquiry-based methods, unlike traditional methods, allow students to reduce memorization of facts and concepts and seek alternative and important useful scientific techniques in the learning process. The inquiry approach makes students actively engaged by using both science methods and critical thinking skills to answer scientific problems (Gibson & Chase, 2002).

Attitude

Definitions

Thomas and Znaniecki's (1918) study of Polish immigrants is considered the first scientific study, which gave attitude its original status as a psychological concept (Shrigley, et. al., 1988). According to Allport (1968), the concept of attitude "is probably the most distinctive and indispensable concept in contemporary American social psychology" (cited in Ajzen & Fishbein, 1973, p. 59). Andre, Whigham, Hendrickson, and Chambers (1999) viewed the complex dynamic interrelationships that exist in attitudinal research as

> ...studying attitudes is not simple. Complex, dynamic, developmental relationships exist between variables such as positive affect toward subject matter domains, perceived competence in particular domains, subject matter course selection, and career choice. Students' prior-acquired attitudes, beliefs, and values, combined with parental and social (peers and other significant adults) demands, students' own abilities and achievements, opportunities afforded by economic status, and locale, and other exogenous variables interact with contextual factors to influence students' behaviors and choices at any given point in time. These variables interact over developmental time. (p. 720)

Attitude is a mental state, integrated with feelings, in which a person can want or reject a certain object (Koballa, 1988; Shrigley, Koballa, & Simpson, 1988; Simpson, Koballa, Oliver, & Crawley, 1994). Also, attitude may be defined as "the emotional orientation of an individual toward the topic at hand" (Freedman, 1997, p. 343). Rosenberg and Hovlan (1960) have suggested that "attitudes are multidimensional, including cognitive, affective, and conative components" (cited in Ajzen & Fishbein, 1973, p. 41). "Individual's attitude toward any object is a function of the individual's beliefs about the object as well as the implicit evaluative responses associated with those belifs" (Fishbein & Ajzen, 1975, cited in Zacharias, 2003, p. 793).

Historical Background

In 1984, Blosser's ERIC computer search on attitude found 62,417 documents (Shrigley, 1990). Attitude is not a relatively new concept evolved only in the 1900s. In the 1800's, attitude was considered a behavior or motor concept (Shrigley, 1990). Three studies helped attitude to evolve historically within the science of behavior: (a) Thomas and Znaniecki's (1918) study of the new lifestyles of Polish immigrants, (b) the

Hawthorne industrial studies where worker fatigue proved to be as much psychological as physical, and (c) Thurstone's (1928) design of a scale to measure feelings (Shrigley, 1990, p. 99).

The concept of attitude that links to feeling became worthy of study at the time Thomas and Znaniecki's book *The Polish Peasant in Europe and America* was written, but the attitude concept was still considered physical rather than psychological (Shrigley, Koballa, & Simpson 1988). While 18th century artists gave attitude the meaning of "physical posture" such as the pose of a statue, others, like Allport, distinguished attitude as not simply a physical concept, but also as a mental concept (Shrigley, Koballa, & Simpson, 1988).

Attitude is derived from the Lain word "aptus" which meant "fitness" or "adaptedeness" and this perhaps shed light on its physical implication; on the other hand, "aptitude" is a mental or cognitive word (Snow & Lohman, 1984) or mental abilities (Dillon & Watson, 1996), which also derived from the word "aptus," that now indicates a mental concept. According to Dillon and Watson (1996), the work of Thurstone and his supporters led to the proposal, and empirical substantiation, of roughly seven aptitudes that can characterize individuals such as verbal comprehension, word fluency, arithmetic ability, spatial relations, memory span and duration, perceptual speed, and inductive reasoning. In general, the broad concept of aptitude can include conative and affective personalities of people (Snow, 1992). Hence, attitude could have the two aspects, the physical and the mental point of reference (Shrigley, Koballa, & Simpson, 1988). The history of the subject attitude and the attitude research has eventually led to the development of measurements' attitude scales. In addition, theoretical ideas about attitudes in conjuncture with behavior had a huge impact on science attitude research (Koballa & Glynn, 2007).

According to Koballa and Glynn (2007), the philosophy of John Dewey also inspired attitude research in science education. He recognized the importance of teaching scientific attitudes as an aspect of educating reflective thinkers in the inaugural issue of the *General Science Quarterly*, now known as *Science Education* (p. 77). Dewey believed that science instruction should foster (a) mental attitudes as intellectual integrity, (b) interest in testing opinions and beliefs, and (c) open-mindedness rather than communicate a fixed body of information (p. 77).

In the 1960s, research on students' science attitudes surfaced in the science education literature (Koballa & Glynn, 2007). There are two ways of looking at attitude related to science: "attitudes toward science", which is student's affect toward science, and "scientific attitude" also called "scientific attributes" that has the cognitive orientation that one would think like a scientist (Koballa & Glynn, 2007). In the 1970s and 1980s research on student's attitudes towards science expanded rapidly with the emergence of Robert Shrigley who worked intensively on science attitude and developed his Likert-type attitude instrument.

Recently, the decline of young people enrolling in science classes and pursuing scientific careers, as well as their lack of enjoyment in science classes have led science researchers to pay more attention towards science attitude research (Osborn, Simon, & Collins, 2003).

Attitude Towards Science

Attitude towards science is not a clear cut concept. It is "somewhat nebulous, often poorly articulated, and not well understood" (Osborne, Simon & Collins, 2003, p. 1049). However, across the field, there was significant documentation of an affective set of behaviors that connect with science education, as follows:

> (a) the manifestation of favorable attitudes towards science and scientists, (b) the acceptance of scientific inquiry as a way of thoughts, (c) the adoption of 'scientific attitude', (d) the enjoyment of science learning experiences, (e) the development of interest in science and science-related activities, and (f) the development of an interest in pursuing a career in science or science related work (Osborne, Simon & Collins, 2003). (p. 1053)

Thus, the field viewed the makeup of attitude towards science as rather complex, consisting of more than one construct. This led investigators to consider a wide variety of constructs when measuring attitudes to science (e.g. Shrigley, Kobala, & Simpson, 1988). Osborne, Simon and Collins, (2003) has portrayed components incorporated by researchers that are used in their measures of attitude to science:

> (a) the perception of the science teacher, (b) anxiety toward science, (c) the value of science, (d) self-esteem at science, (e) motivation of science, (f) enjoyment of science, (g) attitudes of peers and friends towards science, (h) attitudes of parents towards science, (i) the nature of the classroom environment, (j) achievement in science, and (k) fear of failure on course. (p. 1054)

Attitude towards science has been part of the literature of science education research in science education for a long time (Atwater, Wiggins, & Gardener, 1995; Freedman, 1997).). For the past three to four decades, the science education research community has focused on investigations of students' attitude towards studying science (Osborne, Simon & Collins, 2003). Gibson and Chase (2002) claimed that attitudes towards science are developed at early age of child education, and it is tough to alter once children reach middle school. The combination of a decline in the interest of young students in pursuing scientific careers, and scientific ignorance among people especially in the last decade (Osborne, Simon & Collins, 2003), has led science education researchers to emphasize this subject. Robert Shrigley was one of the pioneers for his research on teacher attitudes (Rice & Roychoudhury, 2003). Shrigley (1974) reported that "many elementary teachers have less than a positive attitude toward science is one of the truisms of American education" (p. 243).

Having a less positive attitude towards science could be related to a reduction of self confidence. Harlen (1997) is among researchers who have studied this phenomenon. He found that elementary teachers in England listed science 8th out of 11 different subjects according to their confidence in teaching all the subjects. Those who had extra science courses in their schooling had a higher level of understanding in science and, therefore, their confidence in teaching science courses was higher (Harlen, 1997). Other studies have shown that taking extra science courses increased preservice science teachers' confidence without, however, having an effect on their science content knowledge (Wenner, 1993). In general, studies have shown that students with extracurricular science activities such as science clubs, science affairs, reading science books, and watching science movies have positive attitude towards science (Hofstein, Maoz, & Rishpon, 1990; Cantrell, Young, & Moore, 2003).

Attitude Towards Science and Science Inquiry

Inquiry is a term that has been used since the late 1950s post-Sputnik era. Since then, it has become a prominent theme in science education (R. D. Anderson, 2007).

Inquiry "refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world" (NSES, 1996, p. 23). R. D. Anderson (2007) found that there are three main usages for inquiry that NSES has portrayed: (a) scientific inquiry, (b) inquiry learning, and (c) inquiry teaching.

Scientific inquiry. "Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (NSES, 1996, p. 23). Scientists' work, investigations, and their abilities to do and understand are called inquiry (R. D. Anderson, 2007).

Inquiry learning. Inquiry learning is an active process in which "learning science is something that students do, not something that is done to them. Hands-on activities and minds-on experience as well" (NSES, 1996, p. 2). Students can also learn to do a variety of things which is the essence of a multifaceted inquiry.

> [This] "involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results." (p. 23)

Inquiry teaching. NSES described inquiry as not just a process where students learn skills such as observing, inferring, and experimenting: "inquiry is central to science learning" (p. 2). Therefore, inquiry is central to teaching as well (R. D. Anderson, 2007). However, NSES emphasized that the use of inquiry "does not imply that all teachers should pursue a single approach to teaching science. Just as inquiry has many different facets, so teachers need to use many different strategies to develop the understanding and abilities" (p. 2).

Hence, there is a link between inquiry learning on the part of students and inquiry teaching on the part of the teachers using multiple teaching strategies. Even more, by doing inquiry learning, students do their activities, develop knowledge, and understand scientific ideas, analyze them in a way that resemble those of scientific inquiry. The three terms scientific inquiry, inquiry learning, and inquiry teaching have their own distinction, yet they also have many connections (R. D. Anderson, 2007).

According to the 1996 National Science Education Standards (NSES, 1996), teaching science using inquiry strategies gives teachers skills that can be used to develop student abilities and to strengthen their understanding of science. Similarly, the American Association for the Advancement of Science (AAAS, 1993) supports science curricula that engage students to use inquiry. Hodson (1990) has argued that inquiry-based learning methods are effective approaches for students to learn science. The National Research Councils' (NRC) *Inquiry and National Science Education Standards* (2000) is another recent publication that emphasizes science inquiry in the classroom. Studies show that middle and high school students who have used inquiry-based science activities in laboratories were more motivated and achieved better in science than their counterparts who had used a traditional science method-learning such as lectures, note taking, and lab demonstrations (Gibson & Chase, 2002). In the earth science field, a study by Mao and Chang (1998) compared eight weeks of traditional lecture-type teaching to eight weeks of inquiry-based teaching on secondary students' achievement. It was revealed that students who learned through an inquiry approach scored higher on the achievement test than those who learned using the lecture based approach. They "suggested that it can be beneficial for students to learn science through the inquiry approach" (p. 99).

Other studies have shown that students who use inquiry-based learning have improved attitudes towards both science and school (Selim & Shrigley, 1983; Shrigley, 1990). Tretter and Jones (2003) found the use of inquiry-based teaching style has no dramatic overall achievement on students, but had positive effect in students' participation and higher classroom grades. He also added, developing positive attitude toward physical science can be achieved by the use of inquiry-based teaching if the goal of education goes beyond test scores. In a study performed to assess a model inquiry-oriented environmental science course offered to preservice elementary majors at the University of Montana, it was found that exposure to an inquiry-based environmental science course could promote at least short-term change regarding student attitudes involving social change. Their mean score in the scale of attitudes to scientific inquiry indicated students had more positive attitudes about inquiry as a process in science (Fletcher, 1996, p. 9).

Implicit inquiry-oriented. The implicit approach was adopted in most of the 1960s and 1970s curricula (e.g., Physical Science Study Curriculum and the Biological Sciences Curriculum Study) (Khishfe & Abd-El-Khalick, 2002). This approach "advocates the use of hands-on inquiry-oriented activities and/or science process skills of Nature Of Science NOS" (Khishfe, et. al, 2002, p. 553). Research has shown that this approach was not effective because it lacked explicit references to NOS that would help students develop accurate and informed views of science (Akerson, Abd-El-Khalick, & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002).

Explicit and reflective inquiry. Explicit and reflective inquiry is a more advanced approach, and uses elements from history and philosophy of science and ways of instruction that focus on different aspects to improve students' conceptions or views of NOS (Khishfe & Abd-El-Khalick, 2002). This approach has been used to promote teachers' NOS views as follows:

> "teachers were first explicitly introduced to certain NOS aspects and then provided multiple structured opportunities to reflect on these aspects in the context of the science-based activities in which they were engaged or science content they were learning to help them articulate their views of the target NOS aspects and develop coherent overarching NOS frameworks." (p. 554)

The explicit and reflective approach can improve not only teachers' but also students' views of NOS. It is thought to be more effective than the implicit approach in helping students and teachers construct their own conceptions of abstract scientific ideas associated with "high-level" scientific subjects such as atomic theory (Akerson, Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002). The explicit and reflective approach to inquiry requires students to create their own ideas while consulting with teachers for assistance. According to Piaget "the goal of education should be to form the minds which can be critical, can verify, and not accept everything offered" (1964, p. 5).

Technology and the Use of Simulations

Technology and science are interconnected or meshed together. Technology such as the use of computers can provide the tools that promote the understanding of natural phenomena (NRC, 1996, p. 24). Science and technology are natural combination, and it is perhaps difficult to see teaching science without the use of technology (Norman & Hayden, 2002; Flick & Bell, 2000). Students have benefited from the use of technology in the science classroom in both content and reasoning in the form of modeling, data analysis, and data representation (Songer, 2007).

Technology may help students achieve higher levels of understanding science. Computers, for instance, help educators to offer active lessons and bring hands-on learning that could match students learning styles (Gardner, 2000). Studies show that interactive computer programs where students can utilize data, graphics and even text are helpful in the science education field (Martinez-Jimenez, Pontes-Pedrajas, Polo, & Climent-Bellido, 2003). McKenna, Avery and Schuchardt (2000) have identified several opportunities from including the technology into instruction: (a) increasing students learning; (b) offering students and teachers a new way to think and communicate; (c) expanding the emphasis on problem solving; and (d) allowing students to learn higher level skills such as embedding learning in relevant contexts, critical thinking, goal setting, planning and self monitoring. Similarly, the American Association for the Advancement of Science (AAAS, 1993) and the National Research Council (NRC, 1996) have recommended the use of technology in science inquiry and science learning, which requires engaging students to think scientifically, gather and analyze data, solve problems, and bring scientific reasoning. In the light of all of those requirements of students, technology can be an important factor in supporting students learning science utilizing scientific methods (Songer, 2007). For example, simulations and visualization tools are technologies that support the idea of students' critical thinking about a scientific phenomenon, and be able to compare it with the real world (Songer, 2007).

Computer Simulations

Simulation is defined as "the use of the computer to imitate dynamic systems of objects in a real or imagined world" (Akpan & Andre, 2000, p. 300). According to Alessi and Trollip (2001), "An educational simulation can be defined as a model of some phenomenon or activity that users learn about through interaction with the simulation" (p. 213). Simulations "involve some kind of model or simplified representation" (Thomas & Neilson, 1995 p. 21). Educational simulation allows the presentation of situations to be less dangerous, manipulate different variables, provide better experimental conditions, and even bring the down the cost compared to the real situation (Martinez, et al., 2003). It helps simplify models, allows adding elements that are not present in the real world, and makes complex phenomena easier to the learner (Alessi & Trollip, 2001). Simulations give a learner ways to investigate phenomena that can be dangerous, time consuming, or occur at the speed of light (Doerr, 1997).

Similarly, simulations allow students to ease access to an object domain and can provide feedback or hints on the students' experiments (Alessi & Trollip, 2001), which may help develop their conceptual understanding of the scientific principle (Laurillard, 1993). Moreover, simulations can reduce the complexity of a system, and provide students of different ages, abilities, and learning levels access to "information-laden representations of complex domains", such as physics, mathematics, chemistry, history, and many more (Rieber & Others, 1996, p. 615). Simulation may improve learner's ability to predict a reasonable explanation for abstract concepts that are often found in science (Zacharia & Anderson, 2003).

Zacharia and Anderson (2003) investigated the effects of interactive computer-based simulations that are presented prior to inquiry-based laboratory experiments on students' conceptual understanding of mechanics. The participants of this study were 13 postgraduates, 4 in-service and 9 pre-service science teachers who signed up for a conceptual-based survey course in physics. Semi-structured interviews were used to assess their ability to predict about the phenomenon, and their conceptual understandings were assessed using conceptual tests. The results indicate that the use of simulations not only improved the students' ability to make acceptable predictions and explanations of the phenomena, but also fostered a significant change in the physics content areas (Zacharia & Anderson, 2003, p. 618).

Jimoyiannis and Komis (2001) studied, of 15-16 years old students to determine the role of computer simulations in the development of functional understanding of two concepts of velocity and acceleration in projectile motions. Both experimental and control groups received traditional classroom instruction on the two topics; only the experimental group received the computer simulation. Their analysis founds no differences in students' achievement between the groups with traditional instructions only. However, analysis showed that students who used computer simulations improved significantly. The study concluded that working with computer simulations reinforces students' conceptual change in a gradual process, and "that computer simulations could be used complementary or alternative to other instructional tools in order to facilitate students' understanding of velocity and acceleration" (p. 201).

Another study was done by Hakerem, Dobrynina, and Shore (1993) in which high school students used computer simulations developed at Boston University to model the three-dimensional structure of molecules and the hydrogen bond network that holds water molecules together. This study tested (a) preconceptions concerning the molecular structure of water; (b) the effect of making and testing predictions using visual, interactive computer simulations on students' conceptions of the microscopic properties of water; and (c) aspects of the simulations that were most helpful in promoting conceptual change. The study concluded that (a) teaching models used in the class changed from teacher-centered to more student-centered; (b) students were on task for most of the time they used the computers; (c) computer simulations helped students with misconceptions related to the microscopic and macroscopic properties of water change (water molecules, the structure of molecular water in ice, and vapor in addition to the relationship between the kinetic energy of particles and their temperature); and, (d) there was no significant differences between the preconceptions held by students with strong science backgrounds and those who had little formal science instruction.

Akpan (2001) inserted computer simulations into biological instruction to help students better understand science concepts. Students participating in the study had no prior experience in the use of a simulated interactive dissection. The ninety-five participants in academic biology classes were involved in the dissection of earthworm as a scheduled laboratory experiment. The design of this study was a two group pre-treatment and post-treatment comparison using hands-on method of dissection as the control treatment before or after students used the computer simulation of dissection as experimental treatment. The treatment group that completed the simulation activities before the actual hands-on dissection performed significantly better on the achievement posttest and dissection performance test than the other groups. Simulations used before actual dissections may enhance dissection performance, and experiential simulations facilitate learning from subsequent didactic instruction.

Chemical equilibrium and thermodynamics are physical science topics that high school and undergraduate chemistry students find difficult to understand because of the huge numbers of conceptual difficulties they encounter (Banerjee, 1995; Tyson, Treagust, & Bucat, 1999). A series of simulations that are adapted to Equilibrium Games of Lees was used to show partitioning of a substance between two phases. In this study, the simulations mimic the microscopic equation that lead to a dynamic equilibrium. In a pilot study the simulations were given to four different audiences: grade 12 school students, student teachers, experienced teachers, and college lecturers. Each trial of the simulations was modified from the original Games (Huddle, White, & Rogers, 2000). The finding from the study was that brighter students, and students who had some understanding of chemical equilibrium before they played the Games, had greater benefit than those with very poor understanding of the equilibrium concept.

Le Chat (Paiva, Gil, & Correia, 2002) is a computer simulation-based graphical illustration of chemical equilibrium that is made for high school and freshmen university students, but also can be used with advanced students. The Le Chatelier's principle illustrates the movement towards equilibrium for reactions in a gas phase, as well as the changes produced in the equilibrium state. Le Chat defines "simulation as a plot of concentration of partial pressure versus time for a specific chemical system with given initial conditions" (p. 640). According to Le Chateier's principle, in any reaction, the forward rate of reaction would be greater than the reverse rate of reaction until the system reaches the equilibrium state; on the other hand, "the equilibrium law relates to the concentrations of reactants and products at equilibrium" (Tyson, Treagust, & Bucat, 1999, p. 555). During the simulation, the free energy is plotted and students can watch the change until it reaches equilibrium.

Simulation can also be found in activities related to environmental science and chemistry. The difficulties in carrying out active environmental chemistry or chemical oceanography are obvious. They are expensive, require a lot of time and participation, are difficult to coordinate with teaching activities during the time of the course, and much depends on the weather conditions. Simulation of estuarine mixing is an example in environmental chemistry, achieved by the countercurrent mixing of seawater with river water. To illustrate this type of simulation, mixing of seawater and river water is performed in a series of eight tanks situated at ascending levels in which the water of greatest salinity is at the lowest level (Ortega, Forja, & Parra, 2001). A substance material balance would establish the relationship between the salinity in each tank and the water flows between tanks.

In science in general, and in chemistry or physics in specific, many scientific concepts are abstract and therefore hard for students to visualize. For instance, to teach thermodynamics in a way that allows learners to comprehend the concept of connecting the macroscopic properties of matter such as temperature and pressure to microscopic properties such as momenta and energies require a computer-simulated program (Cox, Belloni, Dancy, & Wolfgang, 2003). To provide such connections one has to think of an effective picture to illustrate the concept to the learner. In older ways of teaching the kinetic model of gas, the learner would not be able to grasp a microscopic concept easily. With advances in the technology of computer simulation programs, the learner could be able to understand the physical meaning of gas laws from a microscopic level (Imai, Kamata, & Miura, 2003).

Computer-assisted instruction (CAI) and especially the use of simulations has helped learners in the science classroom, and eased their learning, yet when mixed with the hands-on laboratory experiments, students could get even higher achievement (Deniz & Cakir, 2006). Despite the benefits that computer simulations provide to the science field and to the science classroom, some researchers suggest that hands-on experience should not be replaced by the use of simulations due to the need for development of manipulation lab skills that students can obtain by using hands-on experiments (Winders & Yates, 1990). Similarly, science curriculum must include hands-on work especially in life science, and computer simulations should not completely replace real world experimentation (Murphy, 1986; Richards, Barowy, & Levin, 1992). Nonetheless, computer simulation can help minimize difficulties related to laboratory experiments and improve students' outcomes (Dewhurst, Hardcastle, Hardcastle, & Stuart, 1994). Hands-on science and the use of simulations can be integrated in the science classroom.

Whether with the use of hands-on or the use of computer simulations, students have the tendency to learn science in a variety of different ways. According to Norman and Hayden (2002), different students learn in different ways, and different students achieve different levels of understanding to a subject matter depending on their interests and abilities. The use of simulations may address multiple learning styles that lead to knowledge construction and, therefore lead students to better understand science (Norman & Hayden, 2002). According to Felder (1996), students indeed are characterized by strengths and preferences that are part of different learning styles which enable them to analyze subject matters differently. Felder's Learning Model categorizes student's preferred learning style into four dimensions. His Index of Learning Styles (ILS) scale has four dimensions: Active-Reflective, Sensing-Intuitive, Visual-Verbal, and Sequential-Global. Felder's Model can be utilized as a tool for science students to reflect on their understanding of science concepts and perhaps a way to identify student's misconceptions when their learning styles are diagnosed.

Learning Styles

Researchers have found that students have different learning styles. They can achieve learning tasks in many different ways (Baldwin & Sabry, 2003). Students learn at different rates, focus and perceive different types of information according to their preferences (Felder & Silverman, 1988; Felder 1993). Because of students differences in learning, students are apt to assimilate information in ways that characterize their styles. That is, some individuals like to work with facts, data, and algorithms; some focus on theories and a mathematical framework. In different cases, students tend to prefer visual prospectives, such as pictures and diagrams; others use the verbal aspect of learning. While some students like to learn actively and interactively, other students tend to be introspective and work in an individual manner (Felder, 1996)

Cognitive Versus Learning Styles

Cognitive styles represent psychological characteristics or traits of people, such as introverted-extraverted, abstract-concrete, realistic-artistic, reflective-impulsive, dependent-independent, which influence how individuals perceive and organize information from their surroundings (Harrison, Andrews, and Saklofske, 2003). Learning styles, on the other hand, are often used as a metaphor to represent individual differences in learning (Price, 2004). "Learning styles are self-reported accounts of an individual's preferences for and perceptions of how they process information" (Price, 2004, p. 683).

History of Learning Styles

The idea of classifying people has a long history before the Myers' research and the production of a questionnaire type indicator. Learning styles or cognitive style can be traced back to the ancient Greek Hippocrates (Ouellette, 2000). Learning styles has been part of the field of science, and particularly in the field of medicine, for hundreds if not thousands of years. The term learning styles was not used then, but people have observed differences in human nature (Hedges, 1997). In ancient times, Hippocrates, the Father of Medicine, argued that observed differences between people could be divided into four groups, which he named temperaments (Hedges, 1997). He maintained that each temperament was generated by the inequality in secretions coming from the heart, Sanguine; the yellow bile attached to the liver, Choleric; the Phlegm by the lungs, Phlegmatic; and the kidneys that produce black bile, Melancholic (Ouellette, 2000; Hedges, 1997). Hippocrates' ideas were so popular that many years later, the Swiss-born renaissance healer Paracelsus (1439-1541) was drawn towards them. He eventually added to the four temperaments which he named "Nymphs, Gnomes, Sylphs, and Salamanders." (Hedges, 1997). The rise of interest in the studies of personality has made scholars in the field continue to classify human nature into four temperaments with minor changes to the four basics groups (Hedges, 1997).

In his 1923 book *Psychological Types*, Jung evaluated the history of psychological typologies from classical literature and poetry through the writings of William Jemes as a beginning for his own work. His work, which focused on the "mind's mental process," allowed him to break away from the four temperaments (Hedges, 1997). His central work leaned heavily on the distinction between introverted and extraverted attitudes (McCrae & Costa Jr.1989). He further added that people relate to the world through two different sets; the rational (or judging) functions of thinking and feeling, and irrational (or perceiving) functions of sensing and intuition (McCrae & Costa Jr., 1989). Carl Jung claimed that although people have the same multitude of instincts that are directed by personal choice, yet they are different and with predictable patterned behavior (Hedges, 1997; Denham, 2002). Since human behavior is predictable, Jung suggests, it is therefore classifiable (Denham, 2002). Jung's theory suggested that humans have preferences in specific ways of purposes and living and perhaps this is why people have different needs, requirements, principles, and drives (Hedges, 1997).

Learning Styles Models

The Myers-Briggs Type Indicator (MBTI). This instrument classifies students according to their personalities, and is based on Jung's theory (McCrae & Costa Jr., 1989; Felder, 1996; Miller, 2001). The MBTI model classifies individuals into 1 of 16 qualitatively different types that are formed by combination of the four dichotomous preferences (McCrae & Costa Jr.1989). Individuals might be: (1a) extroverts: gregarious, tend to be social with the outer world in society; (1b) introverts: gets their knowledge and solutions from the inner world of ideas; (2a) sensors: focus on the facts and procedures, practical and detail-oriented; (2b) intuitors: concept-oriented or imaginative, focus on the possibilities aspects of a problem; (3a) thinkers: decisions based on logical orientation and logical thinking that follows certain rules of logic; (3b) feelers: judgments are based on personal and humanistic approach or appreciations; (4a) judgers: complete data is unnecessary as long as it does apply to what these people believe; and, (4b) perceivers: they adapt to changing circumstances and insist to find conclusion by obtaining more data that will bring closure (Felder, 1996).

Kolb's Learning Style Model. Kolb's model stems from his learning styles theory that is based on four dimensions, which can be paired into: (a) Concrete experience and abstract conceptualization; (b) active experimentation and reflective observation (Kolb, 1984; Smith & Kolb, 1986). In this model, individuals are classified according to their preferences for one of these two continuums that is broken down into four quadrants: (a) Divergers: individuals who combines concrete and reflective, tend to explain how things are related to their experience; (b) assimilators: individuals who combines reflective and abstract, tend organize information and expertise in logical and abstract thinking; (c) convergers: individuals who combines abstract and active, tend to apply ideas well and learn by trial-and-error; (d) accommodators: individuals who combines concrete and active, tend to solve problems with logical reasoning (Kolb, 1984).

Felder-Silverman Learning Style Model. This model was developed by Richard Felder & Linda Silverman for use by teachers and students in engineering and science (Felder, 1993, 1996; Felder & Silverman, 1998). Some of its five protocols replicate aspects of the Myers-Briggs and Kolb models. For instance, (sensing/intuitive) is present in the Myers-Briggs, and (active/reflective) is found in Kolb's model (Zywno & Waalen, 2002). Felder and Silverman also added three other protocols: (visual/verbal), (inductive/deductive), and (sequential/global). The model has five different learning dimensions, but the Index of Learning Styles (ILS) questionnaire developed by Felder and Soloman later address only four of the model dimensions (Felder 2002).

The Felder-Sliverman model describes student's learning style through four questions that ask:

1. What type of information do students preferentially perceive? Sensory, such as sights, sounds, physical sensations; or intuitive, such as memories, thoughts, insights.
2. What kind of external sensory tools are most effectively perceived? Visual, such as pictures, diagrams, flow charts, demonstrations; or verbal, such as, written and spoken explanations.

3. How do students prefer to process information? Actively by engaging in a physical activity; or reflectively through introspection.
4. How do students characteristically progress towards understanding: sequentially, such as step-by-step logical work; or globally, as a whole?
5. With which organization of information is the student most comfortable: inductive-facts and observations are given, underlying principles are inferred; or deductive-principles are given, consequences and applications are deduced? (Felder & Brent, 2005)

According to Felder and Silverman (1988), teaching style may also be defined in terms of the answers to five questions, namely:

> (a) what type of information is emphasized by the instructor: concrete-factual; or abstract-conceptual, theoretical? (b) What mode of presentation is stressed: visual-pictures, diagrams, films, demonstrations; or verbal-lectures, readings, discussions? (c) How is the presentation organized: inductively—phenomena leading to principles; or deductively—principles leading to phenomena? (d) What mode of student participation is facilitated by the presentation: active—student talk, move, reflect; or passive—students watch and listen?, and (e) What type of perspective is provided on the information presented: sequential—step-by-step progression (the trees); or global—context and relevance (the forest)? (p. 675).

The Five Dimensions of Learning Styles

Sensing and intuitive learners. Sensing learners are concrete, practical, and try to solve things the easy way by using facts. Intuitive learners on the other hand like to be innovative and prefer theories and meanings.

Visual and verbal learners. Visual learners prefer to view pictures, diagrams, flow charts, films and other documentaries that enable them to remember the whole idea or subject. Verbal learners tend to learn more out of written and spoken dialogues.

Active and reflective learners. Active students prefer to work in groups, where each member in the group takes turns explaining what he/she learned, and guess on what answers might be required for questions that are going to be asked in a test. Reflective students on the contrary, like to touch base on something and not tend to memorize the material. Unlike their counterparts, reflective students tend to work alone.

Sequential and global learners. Sequential students are linear, and learn through logical and orderly small steps so they can relate the subject matter to what they already know. Global students look at the big picture and get an overall overview.

Inductive and deductive learners. Inductive students tend to prefer the material to lead from specific to general; while deductive students prefer the subject that leads from the general to the specific (Felder & Silverman, 1988; Felder, 1996; Felder & Brent, 2005).

Learning Styles Definitions

There have been many definitions introduced about learning styles and cognitive styles in the literature. Before the mid-70s, researchers defined cognitive styles as concerning how individuals process information and how each individual's perceptions were affected (Dunn & Dunn 1999). Then the concept of learning styles started to emerge in the 70s, including Gregorc (1979), Hunt (1979), and Dunn and Dunn, (1999).

According to Dunn and Dunn, learning styles are defined as the way in which each person absorbs and retains new academic information and or skills (1999). Because researchers developed multiple theories about learning styles the literature has other definitions of learning styles as well. James and Gardner (1995) define learning styles as the "complex manner in which, and conditions under which, learners most efficiently and most effectively perceive, process, store, and recall what they are attempting to learn" (p. 20). Keefe (1979) defines learning styles as a set of "characteristic cognitive, affective, and physiological behaviors that serve as relatively stable indicators of how learner perceive, interact with, and respond to the learning environment" (p. 4). Sarasin (1998) defines learning styles as "the preference or predisposition of an individual to perceive and process information in a particular way or combination of ways" (p. 3). Gregorc (1979) defines learning styles from a phenomenological point view as "distinctive and observable behaviors that provide clues about the mediation abilities of individuals" (p. 19). Learning styles is also described in terms of students learning as the educational conditions under which they most likely to learn (Hunt, 1979).

There are many definitions to learning styles, but they have commonalties in terms of characterizing people with more than just one simple personality statement.

Learning Styles and Computer Simulations

The literature on learning styles and computer simulations is limited. Teaching methods help when instructions match students' their learning styles (Trindade, Fiolhais & Almeida, 2002). However, there seems to be little work regarding the relationship between student learning styles and their achievement when taught with simulations. In their studies about learning styles, Felder and Silverman learned that many engineering students understand better through sensory, visual, active, and inductive ways (Felder & Silverman, 1988). Computer simulations can provide a learning environment that passive lectures cannot.

Learning Styles and Academic Performance

Zywno and Waalen (2002) carried out a quasi-experimental study on the effect of learning styles on academic science outcomes in two different learning environments: hypermedia assisted and conventional. The study took place at Ryerson Polytechnic University in Toronto, Canada. Two different instructors with comparable expertise used the same tools so that no course components could be seen as designed to favor hypermedia-instructed students. Two hypothesis were recognized, first that learners would benefit more from hypermedia instruction than conventional instruction. The second hypothesis was that differences in achievement between different styles learners would be minimized in the experimental group, and unchanged in the control group.

Prior academic performance was gathered from the university database, and an academic assessment was used to evaluate achievement in the course. Information about students' learning styles was collected using the ILS questionnaire. And, finally, a 41-item exit survey was used to assess students' attitudes towards hypermedia instruction. The experimental group (n=49) was assigned to the hypermedia instruction whereas the control group (n=45) was taught conventionally. The study used the Felder-Silverman Index of Learning Styles to measure the learning styles differences in a course offered in a hypermedia-assisted mode to the experimental group. It was found there was a statistically significant increase in academic achievement in the hypermedia assisted experimental group compared to the conventionally instructed control group.

Another study was performed to investigate the interaction of student learning style, sensing and intuiting, and presentation mode (either traditional or hypermedia) on student learning in an introductory computer science class. In this study, Avitabile (1998) did not find a significant difference between lecture or multimedia and learning style. Students of both learning styles benefited from multimedia instruction. Therefore, it was concluded that students who took multimedia lessons on computer science did significantly better than those who studied similar concepts using traditional methods.

Despite the many research that support the study of students learning styles to better assist find different instructional methods on how students can learn better. Teaching students to possess one style such as active-reflective or visual-verbal may hinder their learning process (Keefe, 1979; Felder & Sliverman, 1988; Harrison, Andrews, & Saklofske, 2003)

CHAPTER 3

METHOD

This study investigated the achievement of pre-service elementary teachers taking an introductory physical science course that integrates inquiry-based instruction with computer simulations. The hypothesis was that students with certain characteristics would benefit more than others. Analysis would seek to establish if those with better attitudes towards science benefit more, as well as students with different learning styles benefit differentially. This chapter describes the design, sampling, instrumentations, and procedures which were used to collect and analyze data.

Research Design

A version of a causal-comparative design was chosen for the main component of this study because all participants in the three classes were chosen to represent the sample of the study. In this design, participants are not randomly assigned to experimental groups. This study design looks at cause-and-effect relationships; the presumed causes are the learning styles and the science attitudes, and the presumed effect is the science achievement or conceptual understanding (Gall, Gall & Borg, 2003). The quantitative design was Pretest/Posttest for the science conceptual understanding score, which would be a paper and pencil examination. It was pretest-only for the science attitude and learning styles variables.

The process of the study started when the participants took the Science Attitude Instrument, followed by the Felder-Silverman Index of learning styles (ILS), and finally the science conceptual understanding pre-test was administered at the beginning of the semester in the introductory physical science course. At the end of the teaching period of the units, participants would take the conceptual understanding post-test. The pretest and the posttest data were compared for statistically significance differences.

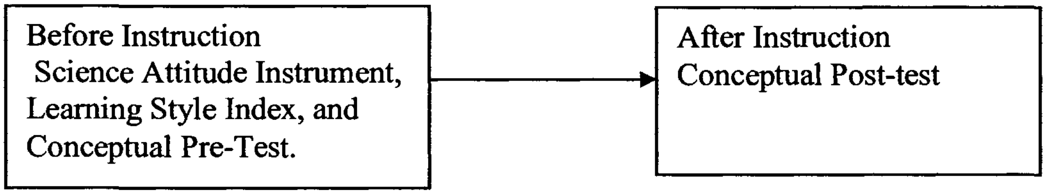


Figure 1. Timing for administration of the three instruments.

In addition to the quantitative data, a qualitative component was added by analyzing the second part of each question in the science achievement instrument that requires explanations of the students' answers. Analyzing students' explanations gave the researcher the ability to triangulate their answers on the multiple choice questions to better understand the actual comprehension level. The full instrument is given in Appendix A. An example follows.

1. When water is vaporized, it is changed to
    A. hydrogen and oxygen
    B. hydrogen only
    C. gaseous water
    D. air, hydrogen, and oxygen
    E. oxygen only

Please elaborate and justify your reasoning? Identify any assumptions you are making.

The answer to the above question is C. The researcher analyzed the participants' explanations to the chosen answer (e.g., Please explain your answer? Identify any assumptions you are making) using a rating scale to be described below.

A random selection of the participants' explanations of the second part of each question was selected from the three classes. Answers that showed no comprehension, little comprehension, fair comprehension, and scientific misconceptions of the second part of each question were selected from each of the three classes for the qualitative analysis. This part of the study gave the researcher extra information on how the participants understood and articulated their knowledge.

Also, a sample of five Ph.D. chemistry majors in their second and third year were selected to answer the achievement test. The test was given to them only one time. This part of the study gave the researcher extra information on how preservice elementary science students' knowledge compare with more advanced students on understanding scientific conceptions, and whether Ph.D. science students still exhibit science misconceptions.

Variables

Three primary variables were considered in this study, two of which are considered independent variables and one the dependent variable. The independent variables for the study were student's learning styles and science attitude. The dependent variable was the student's achievement or conceptual understanding of the nature of matter.

Sampling

To recruit the participants for the study, I met with the instructors of the course. I presented a mini proposal of what I intend to do for my study. I presented the three instruments that were to be used to collect data, and indicated the approximate time it would take to finish each instrument based on timing the instruments on other students. Also, I presented a consent form for the instructors to read and verify, as well as the consent form for the students as mandated by federal law and IRB regulations.

The sample included 68 undergraduate students who were elementary science education majors students, aged 18 – 21 years, enrolled in an introductory physical science course for elementary education majors during 2008 at a Midwestern university. There were three different sections. Two different instructors taught each section separately at a different time. Both instructors were independent in evaluating students and making their own exams for the course. The researcher attempted to recruit all 68 students.

At the beginning of the course in Spring 2008, the Learning Style Instrument was administered to all three classes on the same day. The Attitude Towards Science instrument was given to participants on another day in the same week. The achievement instrument was given to participants at the beginning of Chapter 4 as a pretest, which was February, and was given to the same three classes as a posttest at the end of Chapter 5 approximately six weeks later. The researcher was able to be in charge of the class the entire time when students were filling out the instruments. The researcher also observed all three sections and was able to collect the answers after students were done.

Instruction in the course. The curriculum for the physical science course is different from other science courses. It consists of a group of changing ideas about how the world operates, "together with the dynamic process by which such ideas are developed" (Physical Science and Everyday Thinking, 2007, p. iv). There are different process involve such as creative thinking, experimentation, observation and logical reasoning.

Students are part of the scientific process. They can make predictions based on their own ideas, perform experiments and record their observations, and based on evidence they gather, they eventually draw their own conclusions. Students in this class work in collaboration with classmates. They work in small groups that allow them to discuss thoughts and ideas among themselves. The small groups bring to the table their consensus on the new idea and share that with the whole class. The three major goals for PSET instructional approaches:

1. To help students develop a deep understanding of physical science ideas that can be used to explain everyday phenomena.
2. To help students become more aware of how their own ideas about physical science curriculum facilitate these changes.
3. To help students practice and develop and understanding of how knowledge is developed within a scientific community and the nature of that knowledge itself. (PSET, 2007, p. IV)

The Small Particle Model of Matter and the Simulator

The Small Particle Model (SPM) was developed by scientists to help understand the behavior of matter under different circumstances (PSET, 2007). Under this model, all materials are made up of small particles, and the changes people observe in the subject matter are due to interactions between particles. The SPM explains many experimental observations of subject matters and their behaviors. Because of its predictive power, SPM is widely used by the scientific community.

PSET has developed a teaching model stemming from the scientific model to help science learners understand science concepts that need more visualization. Matter can be found in three different forms or phases: gases, liquids, and solids. In addition, matter consists of small particles that cannot be seen with the naked eye or with the most powerful light microscope; therefore scientists have worked with computer programmers and developed computer simulations that can help the learning enterprise for this curriculum. In the computer simulations, students do not observe the real particles. They observe visual images that represent the scientists' Small Particle Model of matter. For instance, SPM Gas Simulator shows a representation of a container similar to any container with rigid walls and a fixed top. The simulator also contains an imaginary microscope, called the Ultrascope, which allows students to view the particles of a gas as they might look like according to the SPM. The Ultrascope can magnify up to 3,000,000x, which would allow students to observe the particles of a gas with limited detail.

The Ultrascope magnifies a very tiny and fixed volume of space in the container, approximately 8 × 10^{-21} cubic centimeters. The particles that students observe in the Ultrascope are not real, but the inferences that students make from the observations are inferences about scientists' SPM of matter.

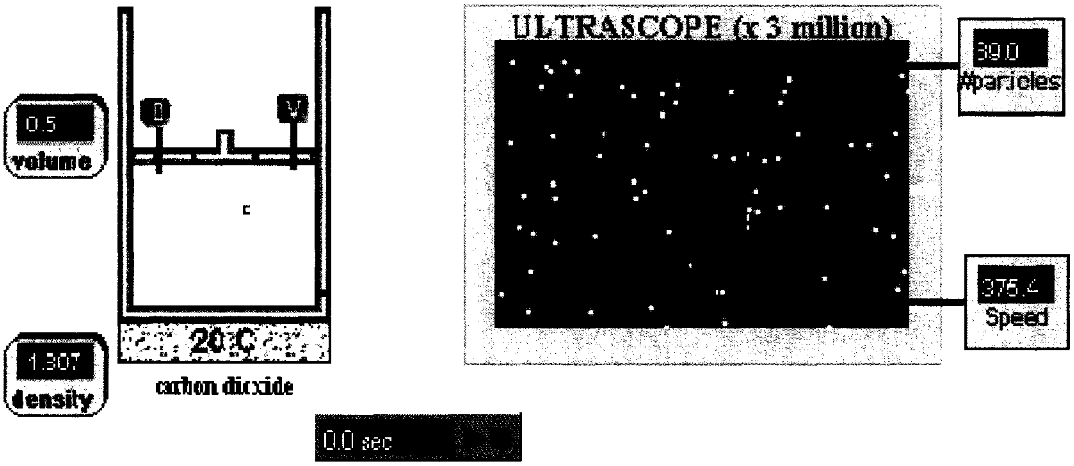


Figure 2. Small particle model simulator.

Instrumentation

Three instruments were used in this study: (a) the Science attitude instrument developed by Robert L. Shrigley, (b) the Felder-Silverman Learning Styles Index (LSI), and (c) a science conceptual test. The LSI corresponds to the learning styles independent variable, and the attitude scale the science attitude independent variable. The conceptual test measured the dependent variable.

Science Attitude Instrument

The science attitude instrument used in this study is a modified version of a scale developed by Robert L. Shrigley. See Appendix B for a copy of the instrument. The original instrument was a Likert-type attitude scale that was developed to assess four variables believed by the researcher to be pertinent in analyzing the attitude of elementary teachers (Shrigley, 1974).

Development. The Shrigley attitude instrument was administered as a pilot study in the fall of 1970 to 89 undergraduate college students enrolled in a professional course in elementary school science teaching at the Pennsylvania State University (Shrigley, 1974). In a pilot study, the college students were asked to respond to each of the 38 attitude statements with five choices: Strongly agree, agree, undecided, disagree, and strongly disagree. "In scoring positive statements the alternatives were weighted 5,4,3,2,1 points. In scoring negative statements, the weights were reversed. No points were given for omissions" (p. 245).

The 38 attitude statements were analyzed on a Likert Scale computer program at the Pennsylvania State University. Only the higher and the lower 27 percent, which was 24 and 24 of the participants', was used to represent the higher and the lower attitude (Shrigley, 1974). A favorable-unfavorable index was chosen for each statement, and by comparing the statements to the criterion groups the neutral attitude statements could be eliminated (Shrigley, 1974, p. 246). The t-scores for differences between the high and the low attitude means on the 38 statements ranged from 0.9 to 9.5, and the reliability for the total scale was 0.91 (Shrigley, 1974).

Reliability. Fifteen statements were dropped from the 38 attitude original statements to get a more "rigorous score of 3.8 as the t-score below which statements were dropped from the scale" (p.246). The remaining 23 statements, 14 positive ones and 9 negative ones, were given to 89 students and resubmitted to the Likert Analysis. "The range of the t-scores on the revised scale was from 3.4 to 9.6 and the reliability coefficient was .92" (p. 246). As Tuckman (1999) states that an alpha of 0.5 is minimally acceptable for attitude tests measurements, this attitude scale should be reliable enough for this study.

Revision. Shrigley's science attitude instrument was revised and given a "through examination of the content and construct validity of the attitude scale" (Thompson & Shrigley, 1986, p. 331). A jury of three science educators recommended 10 statements be dropped because they "did not pertain to the attitude of pre-service teachers toward the teaching of science" (Thompson & Shrigley, 1986, p. 332). Because my study focuses on the pre-service teachers' attitude towards science and not their attitude towards the teaching of science, Thompson and Shrigley's revised attitude scale was not as useful for me as the original scale.

Modifications for this study. In this study I used Shrigley's science attitude instrument, but with two changes. I have used one of the revised statements from Thompson and Shrigley. Statement number 14 was chosen ("I am afraid that students will ask me questions that I cannot answer") to replace statement number 7 on the original Shrigley attitude instrument ("I am afraid that young pupils will ask me science questions that I cannot answer"). I believe that statement number 14 is better constructed than statement 7 in the original attitude instrument.

I have also chosen two recent statements from Tuckman's (1999) math attitude scale, replaced the word "math" with the word "science," and used them to replace two statements from Shrigely's attitude scale. The two statements are:

1. "My mind goes blank and I can't think when doing science." This will replace statement 1 in Shrigley's, which states "I daydream during science classes."
2. "Science is my most dreaded subject." This will replace statement 3, which states "I dread science classes."

Learning Styles Instrument

Another instrument used in this study is a modified version of the Index of Learning Styles. Please see Appendix C for a copy. The original instrument was created by Richard Felder and Linda Silverman in 1988 to explore the learning style differences among engineering students and to provide instructors with a better idea of how to modify their teaching approaches and address student needs (Felder & Spurlin, 2005). The Index of Learning Styles (ILS) consists of 44 questions, with two possible choices for answers for each question that reflect students' preferences within the Felder-Silverman model. For example:

1. I understand something better after I

    a) try it out.

    b) think it through.

In 1991, Richard Felder and Barbara Soloman of North Carolina State University created another version of the instrument to assess preferences on the four scales of the Felder-Silverman model (Felder & Brent, 2005). In 1994, hundreds of responses to Version 1 were gathered and subjected to factor analysis. Items that did not load strongly on single factors were abandoned and replaced by new items, which was revised to create the current version (Felder & Spurlin, 2005). Later on, a corrected version of the instrument was put on-line in 1997 (Felder & Spurlin, 2005; Felder & Brent, 2005). By submitting a completed ILS questionnaire on-line, a person is able to get a profile with scores on all four dimensions, in addition to brief explanations of their significance (Felder & Spurlin, 2005).

There are eight dimensions to the Index of learning Styles. The score on each dimension, or model ranges from 0-11, and the difference between scores for two related dimensions (e.g. Visual score – Verbal score) reflect the student's learning style (Zywno & Waalen, 2002).

VIS													**VRB**
	11a	9a	7a	5a	3a	1a	1b	3b	5b	7b	9b	11b	

Participants who have a difference score of 1-3 are considered balanced on the two dimensions of the learning style scale. Participants who score between 5-7 have a moderate preference for one dimension of the scale. Finally, participants with scores 9-11 have a very strong preference for one dimension of the scale.

The ILS instrument was chosen for this study because it is the most widely used among engineering students (Livesay & Dee 2005). Since engineering is a segment of the science field, the ILS instrument, seems most appropriate for pre-service science teachers. In addition, the scale has strong psychometric qualities, giving the researcher more confidence. Some learning styles instruments are too complicated, such as the Dunn and Dunn model, and others are too general, such as Kolb's model (Zywno & Waalen, 2002). The ILS instrument is more focused on science aspects, which makes it most valid for this study.

Several studies have used the ILS, and considerable response data has been gathered (Felder & Spurlin, 2005). In one study conducted at Iowa State University 129 undergraduate engineering students completed the ILS. In this study, 63% of students were classified as active learners; therefore, 37% were classified as reflective learners. Similarly, 67% of the students were classified as sensing, thus, the 33% remaining were intuitive learners (Felder & Spurlin, 2005). Other studies in many different universities have used the ILS (Zywno, 2002; Zywno & Waalen, 2001).

Reliability. Seery, Gaughran, and Waldmann (2003) established a high test-retest reliability estimate over a four week period in all domains of ILS. It was confirmed that the ILS was a good measurement for learning preferences due to its consistency of scores over a series of running intervals, which indicated good test-retest reliability (Livesay, & Dee, 2005). According to Felder and Spurlin (2005), the correlations reported by Seery et al. provided psychometric quality for the ILS and resulted in score satisfaction of the test-retest reliability of the ILS.

In a study of 255 engineering students at Tulane University, New Orleans, Livesay, Dee, Felder, Hites, Nauman, and O'Neal (2002) found that Alphas for each dimension of ILS ranged from 0.54 to 0.72. In examining the psychometric properties for each of the administrations of the ILS in terms of the Alpha reliability in another five week study of all engineering freshmen at Rose-Hulman Institute of Technology at Terre Haute, Indiana revealed that sensing/intuitor domain had the highest alpha reliability, 0.76, in both test and retest, and the lowest alpha reliability was related with the sequential/global domain which was 0.48 (Livesay & Dee, 2005). In the same study, individual students scores in all four domains were significantly correlated between test and retest, ($p< 0.1$). These results provide additional support for the reliability of the ILS (Livesay & Dee, 2005).

Examining the ILS in a study of 545 students at North Carolina State University resulted in 0.55 to 0.76 Alpha coefficients (Zywno, 2003). Using the ILS, Van Zwanenberg, Wilkinson, and Anderson (2000) studied the learning styles of 139 engineering students and 145 managers at two universities in Newcastle, United Kingdom, with Alphas ranging from 0.41 to 0.65. They anticipated low internal reliability of the instrument because they thought that the ILS should be best used to establish the relative strength of an individual rather than comparing the learning preferences with another person. A psychometric analysis of the ILS at Ryerson University revealed that internal consistency estimates of reliability ranged from 0.53 to 0.70 (Zywno, 2003). Therefore, one would say that the ILS has shown respectable reliability, and is therefore an appropriate instrument for this study.

Achievement or Conceptual Understanding of Science Instrument

The Conceptual Understanding of Science Instrument is an adaptation of an early version of the Particulate Nature of Matter Assessment (ParNoMA) developed by Yezierski. A copy of this instrument can be found in Appendix D. The literature and interview responses from an unpublished pilot study conducted by Yezierski provided distracters for multiple choice items.

Development. According to Yezierski (2002), ParNoMA was developed using Treagust's steps for developing and using diagnostic tests to evaluate students' misconceptions. The topics represented in this instrument are size of particles, weight of particles, phases and phase change, composition of particles, and energy of particles.

The early version of the ParNoMA consisted of 12 multiple-choice questions. It was designed such that the keyed answer described the currently accepted scientific understanding and each distractor was a documented misconception. Four of the items come from a specific study, and relate to the composition of bubbles in boiling water and particulate descriptions of evaporation and condensation. The gas molecules under different pressures item was developed based on another study, and highlights a misconception about pressure changing the size of molecules. The items relating to energy, shape, arrangement, structure, and weight of atoms/molecules and phases are based on the findings of several other studies.

The questions that include pictures of atoms and molecules are shown in circles that represent macroscopic views of containers. Inside circles show atoms and molecules that represent particulate views. The circles are connected with lines that serve as arrows to a point inside the container to indicate an enlargement of view of a microscopic portion of contents.

Validity of Particulate Nature of Matter (ParNoMA). The first ParNoMA Instrument (version 1) consisted of 12 multiple-choice questions, was piloted in the first semester general chemistry class (N =72, Alpha = 0.78). The mean was 5.78 out a possible score of 12 (48.2%) with no ceiling effect in the pilot sample (Yezierski 2002). The new instrument (version 2) consisted of 20 multiple-choice questions, was piloted in a summer 2002 first semester general chemistry class (*N* = 77, Cronbach $\alpha = 0.83$). The pilot study was conducted with college students, and it was expected that college students would score high and likely reveal a ceiling effect if one was inherent in the test. Since the mean of the version 1 was 5.78 out a possible score of 12 (48.2%) (Yezierski 2002), and 15.2 out a possible 20 (78.0%) for version 2, the instrument did not have a ceiling effect in the pilot sample (Yezierski & Birk, 2006). The main purpose for the pilot study was to test the reliability of version 2. The test was reviewed by three college chemistry instructors and two general chemistry teaching assistants, and it was validated based on the reviewers' 100% agreement upon the correct answers (Yezierski & Birk, 2006).

Adaptations of the Instrument for this study. Since this study tackles the issue of pre-service science teachers' misconceptions of the particulate nature of matter, this instrument is highly appropriate. Five questions were chosen from the ParNoMA instrument, and one question was taken from the Physical Science in Everyday Thinking assessment that is administered as a pre-test and post-test by the instructors as part of the introductory physical science course. This created a six question test divided into two parts; first, the multiple choice question, and second, the explanation. Given the length of the class period and the need for open-ended explanations, a total of 6 questions was deemed reasonable for the purpose intended to test the participants in the two units (Chapter 4 and Chapter 5). However, only the first part of the course assessment question (#13), which is now #6 in our instrument, was chosen. The second part of the question, which is (how sure are you about your answer?) was replaced with another phrase (Please elaborate and justify your reasoning?). This way all the six questions of the conceptual understanding test for this study would be consistent on the second part of each question.

Procedures

Protection of Human Subjects

The Institutional Review Board of the University of Northern Iowa approved this research before data was collected. The application indicated the name of the study, the risks and discomfort participants might experience. Also the application assured that there would be no coercion on students to participate in the study. Participants who would agree to participate must write their names and signature, but also have the right to withdraw at any time without any penalty. Participants would submit the signed consent form, which would be kept for the several years that the IRB requires before being destroyed. A copy of the consent form can be found in Appendix D.

Administration of Instruments

I administered the three instruments at the beginning of the physical science classes as close to the beginning of the semester as possible. On the first day of the course, I distributed the science attitude instrument on the tables before students showed up to class. As the time class started, I gave them a verbal explanation of the study including the IRB required explanation that they had the right to stop participation at any time, and there was only minimal risk associated with participation in the study. I then asked them to carefully read the consent letter I provided and sign it if they would like to volunteer in participation in the study. They agreed to participate in the study and agreed to be ready for the other two instruments in the following days. On the second visit to the three classes, I distributed the ILS. Later in the semester, approximately 2 weeks after data about the science attitude instrument and the ILS instrument were collected, I distributed the conceptual science instrument to all students in the three classes before they have started on Chapter 4 as pretest. At the end of the units (Chapter 4 & 5) I gave the same participants the posttest of the conceptual understanding of the nature of matter instrument. The time between the pretest and the posttest was approximately 9 weeks.

Statistical Analysis

After collecting data, it was entered into a Statistical Package for the Social Sciences (SPSS) data file. To answer the research questions I used simple and multiple regression. If probability is 0.05 or less, then the null hypotheses are rejected and the main effect is statistically significant (Pyrczak, 2003). I began by developing descriptive statistics for all results. I also calculated Cronbach's alpha coefficients as a measure of internal consistency reliability for the three instruments.

For the qualitative data analysis, I used three criteria to analyze the second part of each question in the achievement or conceptual understanding science instrument (which is, "Please elaborate and justify your reasoning?"). The criteria are (a) whether the ideas needed are complete, (b) whether the ideas included are accurate, and (c) whether the logical reasoning and clarity of narrative that connects ideas to the phenomenon are established (PSET, 2007). These criteria were used in the PSET curriculum in which students were asked to provide explanations for physical phenomena with a focus on interactions, forces, and energy.

Table 4 shows the rubric that was developed based on the criterions. In addition, the researcher in conjunction with a chemistry professor and the introduction into Physical Science Course teachers laid out a model answer to each of the questions. These comprehensive answers are given below.

Table 4

Criteria for Analyzing the Essay Questions

4 points	3 points	2 points	1 point	0 point
All necessary ideas are included	Most necessary ideas are included	Some necessary ideas are included	Few necessary ideas are included	None of the necessary ideas are included
All scientific information is accurate	Most scientific information is accurate	Some scientific information is accurate	Few scientific information is accurate	None of the scientific information is accurate
All ideas are connected in a logical and clear	Most ideas are connected in a logical and clear	Some ideas are connected in a logical and clear	Few ideas are connected in a logical and clear	None of the ideas are connected in a logical and clear

Complete Answers for Science Achievement Instrument

Please see Appendix A for all questions. Students are evaluated by three criteria: ideas completion, logical reasoning, and clarity.

Question # 1

All scientific ideas are included:

A. Structure of molecules.

B. Kinetic energy.

C. Space between molecules, and

D. Evaporation process, liquid to gas.

The following model would be rated at 4 points based on the three criteria. During a phase change, the structure of ammonia molecules does not change, only space between molecules changes. Therefore a physical change of the molecules does not change the chemical composition of the ammonia. The ammonia particles gain kinetic energy from the surrounding that would help breaks bonds between molecules, so the ammonia lose any order and spread out from one another to form gas or vapor, yet still be composed of the same atoms in the same proportion, one N atom and 3 H atoms.

Question # 2

All scientific ideas are included:

A. Less pressure.

B. Fewer particle collisions.

C. Molecules do not change, and

D. Fewer molecules in the same amount of space.

The following model would be rated at 4 points based on the three criteria. Less pressure indicates that there are fewer particles collisions between carbon dioxide molecules and the walls of the container, but the chemical composition of the molecules would not change. The drop in pressure will allow the fewer molecules to spread out in the same amount of space.

Question # 3

All scientific ideas are included:

A. The structure of the molecules does not change.
B. Kinetic energy.
C. Space between molecules, and
D. Melting process (Solid to liquid).

The following model would be rated at 4 points based on the three criteria. When solid ice melts, the structure of molecules does not change. The molecules gain kinetic energy and begin to vibrate, and therefore, bonds between molecules become weak. Since melting is the conversion of a solid to liquid, molecules become free to move and lose their original ordered arrangement. The less organized molecules still composed of the same atoms in the same proportion, one O atom and 2 H atoms.

Question # 4

All scientific ideas are included:

A. Kinetic energy increases.
B. Kinetic energy associated with the motion of molecules.
C. Higher temperature relates to faster speed of molecules, and

D. Temperature of the water is lower than the temperature of the gas.

The following model would be rated at 4 points based on the three criteria. As temperature increases, kinetic energy increases. Since kinetic energy is the energy associated with the motion of an object, higher kinetic energy indicates a faster speed. Consequently, a higher temperature also indicates a faster speed. Since the temperature of the water is lower than the temperature of the gas, the water molecules must be moving slower than the gas molecules.

<u>Question # 5</u>

<u>All scientific ideas are included</u>:

A. Structure of the molecules does not change.
B. Kinetic energy.
C. Space between molecules, and
D. Vaporization process (liquid to gas).

The following model would be rated at 4 points based on the three criteria. During this phase change, when water is vaporized, it turns to gaseous water, but the structure of molecules stays the same. Bonds between water molecules weaken as it gains kinetic energy. Since water converts to gas, the molecules will be more spread out from one another but still be composed of the same atoms in the same proportion, one O atom and 2 H atoms.

CHAPTER 4

RESULTS

The main purpose of this study was to determine the effect of learning styles and attitude toward science on preservice elementary teacher's conceptual understanding of the nature of matter in a simulation-based learning environment. These pre-service elementary teachers were enrolled in an introductory physical science course that integrates inquiry-based instruction with computer simulations. Following the theory of learning style given in Chapter 2, it seems reasonable that students with certain learning styles would benefit more than others from a specific learning environment. Further, it seems reasonable that those with better attitudes towards science would benefit more. Therefore, the following four research questions were addressed:

1. Does learning style affect pre-service elementary science teachers' conceptual understanding of the particulate nature of matter in a science class which uses hands-on learning integrated with computer based simulated activities?

Specific Hypotheses:

a. Active learners will exhibit greater change in conceptual understanding of the particulate nature of matter than reflective learners.

b. Sensing learners will exhibit greater change in conceptual understanding of the particulate nature of matter than intuitive learners.

c. Visual learners will exhibit greater change in conceptual understanding of the particulate nature of matter than verbal learners.

d. Sequential learners will exhibit greater change in conceptual understanding of the particulate nature of matter than global learners.

2. Is pre-service elementary majors' science learning in a course using hands-on learning integrated with computer-based simulations related to their attitude towards science?

3. Is pre-service elementary teachers' achievement gain scores affected by attitude and their learning styles?

4. Were preservice elementary science teachers' science misconceptions dissipated over the course of this study?

The rest of this chapter first presents descriptive results for each instrument, followed by inferential results for each research question in turn.

Descriptive Statistics

Science Attitude Survey

The science attitude instrument used in this study was a modified version of a scale developed by Robert L. Shrigley. See Appendix B for a copy of the instrument. The scale as used contained 23 statements, 14 positive and 9 negative. The scoring scale for positive was 5 for strongly agree (SA), 4 for agree (A), 3 for undecided (U), 2 for disagree (D), 1 for strongly disagree (SD). For the negatively worded items scoring was reversed prior to the analysis.

Total usable surveys returned were 67. The overall average mean was 3.13 (SD = .51), representing approximately undecided, midway between positive and negative. The distribution was quite normal as Figure 2 shows. A reliability analysis of the scale was carried out on SPSS, yielding a very substantial Cronbach alpha of .92.

Below is a figure of histogram that represents attitude average for preservice elementary science teachers.

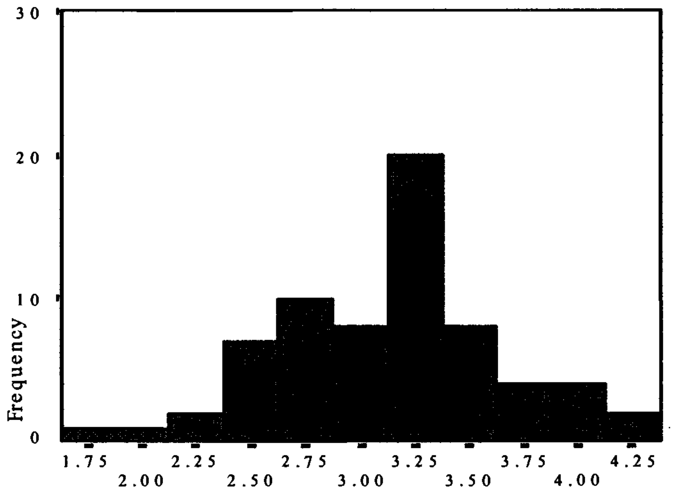


Figure 3. Histogram of overall attitude average for preservice elementary teachers.

In the next section, results are presented by individual item. These results are also summarized in Table 5.

Results for positive statements.

Statement # 2: "I would like to have chosen science as a minor in my elementary education program". The mean was 2.37 (SD = 1.17), n = 67. This mean is towards the left side of the scale, *disagree.*

Statement # 6: "I enjoy manipulating science equipment." The mean was 2.91 (SD = .947), n = 65. This mean is close to the middle of the scale, *undecided.*

Statement # 8: "In science classes, I enjoy lab periods." The mean was 3.75 (SD = .876), n = 67. This mean is tipping towards the right side of the scale, *agree.*

Statement # 9: "Science is my favorite subject." The mean was 2.23 (SD = 1.035), n = 66. This mean is leaning towards the left side of the scale, *disagree.*

Statement # 10: "If given the choice of student teaching, I would prefer teaching science over any other subject in the elementary school." The mean was 1.99 (SD = .945), n = 67. This mean is nearly exactly at *disagree.*

Statement # 12: "I would enjoy helping children construct science equipment." The mean was 3.30 (SD = .976), n = 66. This mean is somewhat to the positive side of *undecided.*

Statement # 14: "I am looking forward to teaching science to elementary children." The return was 67 and the mean was 3.30 (SD = .921). This mean is close to the center of the scale, *undecided.*

Statement # 15: "I enjoy college science courses." The mean was 3.13 (SD = .936), n = 67. This mean is close to the center of the scale, *undecided.*

Statement # 17: "I would be interested in working in an experimental elementary science curriculum project." The mean was 3.00 (SD = .921), n = 67. This mean is right in the middle of the scale at *undecided.*

Statement # 18: "I enjoy discussing science topics with my friends." The mean was 2.31 (SD = .874), n = 67. This mean is on the negative side of the scale, fairly close to *disagree.*

Statement # 20: "I expect to be able to excite students about science." The mean was 3.70 (SD = .697), n = 67. This mean is to the right side of the scale, *agree.*

Statement # 21: "I frequently use scientific ideas or facts in my personal life." The mean was 2.63 (SD = .714), n = 67. This mean is considerably on the negative side of the scale, *undecided.*

Statement # 22: "Pre-supposing adequate knowledge about science, I would enjoy teaching the subject to children." The mean was 3.36 (SD = .865), n = 67. This mean is somewhat on the positive side of *undecided.*

Statement # 23: "I believe that I have the same scientific curiosity as a young child." The mean was 3.21 (SD = .993), n = 67. This mean is leaning towards *undecided.*

Results for negative statements (after reversal)

Statement # 1: "My mind goes blank and I can't think when doing science." The mean was 3.72 (SD = .982), n = 67. This mean is towards the right side of the scale, *agree.*

Statement # 3: "Science is my most dreaded subject." The mean was 3.26 (SD = 1.213), n = 67. This mean is close to the middle of the scale, *undecided.*

Statement # 4: "Science equipment confuses me." The mean was 3.37 (SD = .997), n = 67. This mean is close to the middle of the scale, *undecided.*

Statement # 5: "Science is not an important subject in the elementary curriculum." The mean was 4.39 (SD = .857), n = 66. This was the largest mean of all the items, falling almost between *agree* and *strongly agree.*

Statement # 7: "I am afraid that students will ask me questions that I cannot answer." The mean was 2.97 (SD = 1.014), n = 67. This mean is nearly exactly at *undecided.*

Statement # 11: "My science classes have been boring." The mean was 3.23 (SD = 1.07), n = 67. This mean is close to the middle of the scale, *undecided.*

Statement # 13: "When I become a teacher, I fear that the science demonstrations will not work in class." The mean was 3.31(SD = 1.032), n = 67. This mean is close to the middle of the scale, *undecided.*

Statement # 16: "I prefer that the instructor of a science class demonstrate equipment instead of expecting me to manipulate it." The mean was 2.26 (SD = .914), n = 67. This mean is close to the left side of the scale, *disagree.*

Statement # 19: "Science is very difficult for me to understand." The mean was 3.25 (SD = .997), n = 66. This mean is close to the middle of the scale, *undecided.*

Table 5

Summary for Positive and Negative Statements

Positive	Mean (On scale 1-5)	Negative	Mean (On scale 1-5) after reversal
Statement # 2	2.37 (SD = 1.17)	Statement # 1	3.72 (SD = .982)
Statement # 6	2.91 (SD = .947)	Statement # 3	3.26 (SD = 1.213)
Statement # 8	3.75 (SD = .876)	Statement # 4	3.37 (SD = .997)
Statement # 9	2.23 (SD = 1.035)	Statement # 5	4.39 (SD = .857)
Statement # 10	1.99 (SD = .945)	Statement # 7	2.97 (SD = 1.014)
Statement # 12	3.30 (SD = .976)	Statement # 11	3.23 (SD = 1.07)
Statement # 14	3.30 (SD = .921)	Statement # 13	3.31(SD = 1.032)
Statement # 15	3.13 (SD = .936)	Statement # 16	2.26 (SD = .914)
Statement # 17	3.00 (SD = .921)	Statement # 19	3.25 (SD = .997)
Statement # 18	2.31 (SD = .874)		
Statement # 20	3.70 (SD = .697)		
Statement # 21	2.63 (SD = .714)		
Statement # 22	3.36 (SD = .865)		
Statement # 23	3.21 (SD = .993)		

Achievement (Conceptual Understanding of Science) Test

The Conceptual Understanding of Science survey is an adaptation by the researcher of the Particulate Nature of Matter Assessment (ParNoMA) developed by Yezierski. A copy of the instrument can be found in Appendix D.

Pretest Results. The scoring scale for the 6 multiple choice questions was 1 point each. Thus, the total possible score for the quantitative part of the questions was 6 points. The mean was 2.36 (SD = 1.43) out of 6 points. The distribution was reasonably normal. The return was n = 65. Reliability analysis of the scale yielded a Cronbach's alpha of .52, which is minimally acceptable (Tuckman, 1999).

Results for the six multiple choice questions follow. See Appendix A for the questions. For the sample, question #4 was easiest, with 74% choosing the correct answer. Question #5 was the hardest, with only 7% of the respondents choosing the correct answer. Results by question at both pretest and posttest are given in Table 6.

Question #1: Twenty-three (32.9%) participants chose the correct answer.

Question #2: Twenty-eight (40.0%) participants chose the correct answer.

Question #3: Thirty-nine (55.7%) participants chose the correct answer.

Question #4: Fifty-two (74.3%) participants chose the correct answer.

Question #5: Five (7.1%) participants chose the correct answer.

Question #6: Eighteen (25.7%) participants chose the correct answer.

Posttest Results:

The mean at posttest rose to 3.45 (SD = 1.53), n = 65. The distribution is not particularly skewed (.20), but is somewhat flattened (kurtosis = -1.167). The reliability analysis yielded a Cronbach alpha of .56, also low.

Results for the six multiple choice questions follow. See appendix A for the items.

Question #1: Thirty-seven (57%) participants chose the correct answer.

Question #2 Twenty-six (40%) participants chose the correct answer.

Question #3: Fifty-four (83%) participants chose the correct answer.

Question #4: Fifty-five (85%) participants chose the correct answer.

Question #5: Twenty-six (40%) participants chose the correct answer.

Question #6: Twenty-six (40%) participants chose the correct answer.

These results are also summarized in Table 6.

Table 6

Summary of the Pretest and the Posttest Multiple Choice Questions Results

Question	Correct Answer	Pre MCQ Participants Choosing the Correct Answer	Mean/SD	Correct Answer	Post MCQ Participants Choosing the Correct Answer	Mean/SD
Q#1	A	23	.33 (SD = .47)	A	37	.57 (SD = .50)
Q#2	C	28	.40 (SD = .493)	C	26	.40 (SD = .49)
Q#3	C	39	.56 (SD = .50)	C	54	.83 (SD = .38)
Q#4	B	52	.74 (SD = .44)	B	55	.85 (SD = .36)
Q#5	C	5	.07 (SD = .26)	C	26	.40 (SD = .49)
Q#6	E	18	.26 (SD = .44)	E	26	.40 (SD = .49)

Pretest Essay Results.

The second part of each of the first five questions was scored as 4 points. Only 1 point was given for the sixth question, “How sure are you of your answer?” for choosing the answer “very sure,” and half a point for choosing the answer “somewhat sure” if the multiple choice answer for the same question was correct. The total possible score for the essay questions was thus 21 points.

The pretest mean was 3.84 (SD = 1.99) out of 21 points possible, n = 65. The score distribution was somewhat positively skewed (1.10), and substantially flattened (kurtosis = 3.75).

Results by Item:

The mean for question 1 was .71 (SD = .655) out of 4. Twenty-six (40.0%) participants scored 0 points, thirty-two (49.2%) participants scored 1 point, and seven (10.8%) participants scored 2 points.

The mean for question 2 was .65 (SD = .672) out of 4. Twenty-nine (44.6%) participants scored 0 points, thirty-one (47.7%) participants scored 1 point, four (6.2%) participants scored 2 points, and one (1.5%) scored 3 points.

The mean for question 3 was .94 (SD = .390) out of 4. Seven (10.8%) participants scored 0 points, fifty-five (84.6%) participants scored 1 point, and three (4.6%) participants scored 2 points.

The mean for question 4 was .82 (SD = .583) out of 4. Eighteen (27.7%) participants scored 0 points, forty-one (63.1%) participants scored 1 point, and six (9.2%) participants scored 2 points.

The mean for question 5 was .60 (SD = .524) out of 4. Twenty-seven (41.5%) participants scored 0 points, thirty-seven (56.9%) participants scored 1 point, and one (1.5%) participants scored 2 points.

The mean for question 6 was .13 (SD = .322) out of 1. Fifty-five (84.6%) participants scored 0 points out of 1, and ten (15.4%) participants scored 1 point out of 1.

Posttest Essay Results.

The posttest essay mean was 5.6 (SD = 2.974), n = 65. This represents a growth of 1.96 points from the pretest. The distribution was substantially normal.

Results by Item.

The posttest essay mean for question 1 was 1.11 (SD = .640) out of 4. Eight (12.3%) participants scored 0 points, forty-four (67.7%) participants scored 1 point, eleven (16.9%) participants scored 2 points, and two (3.1%) scored 3 points.

The mean for question 2 was .94 (SD = .916) out of 4. Twenty-five (38.5%) participants scored 0 points, twenty-three (35.4%) participants scored 1 point, thirteen (20%) participants scored 2 points, and four (6.2%) scored 3 points.

The mean for question 3 was 1.2 (SD = .617) out of 4. Five (7.7%) participants scored 0 points, forty-four (67.7%) participants scored 1 point, fourteen (21.5%) participants scored 2 points, and two (3.1%) scored 3 points.

The mean for question 4 was 1.17 (SD = .876) out of 4. Fourteen (21.3%) participants scored 0 points, thirty-two (49.2%) participants scored 1 point, thirteen (20%) participants scored 2 points, and six (9.2%) scored 3 points.

The mean for question 5 was .92 (SD = .645) out of 4. Fifteen (23.1%) participants scored 0 points, forty-one (63.1%) participants scored 1 point, eight (12.3%) participants scored 2 points, and one (1.5%) participants scored 3 points.

The mean for question 6 was .28 (SD = .415) out of 1. Forty-three (66.2%) participants scored 0 points, and twenty-two (33.8%) participants scored 1 point.

Table 7 represents summary of the pretest and posttest essay results for each question. Table 8 represents summary of the total pretest and the posttest essay results.

Table 7

Summary of the Pretest and Posttest Essay Results by Question

	Pretest Essay Score (% of students)	Posttest Essay Score (% of students)
Q1*	0 (40%), 1 (49%), 2 (11%)	0 (12%), 1 (68%), 2 (17%), 3 (3%)
Q2*	0 (44%), 1 (48%), 2 (6%), 3 (1.5%)	0 (38%), 1 (35%), 2 (20%), 3 (6%)
Q3*	0 (10%), 1(85%), 2 (5%)	0 (7%), 1 (68%), 2 (21%), 3 (3%)
Q4*	0 (27%), 1 (63%), 2 (9%)	0 (21%), 1 (49%), 2 (20%), 3 (9%)
Q5*	0 (41%), 1 (57%), 2 (1.5%)	0 (23%), 1 (63%), 2 (12%), 3 (1.5%)
Q6**	0 (84%), 1(15.4%)	0 (66%), 1 (34%)

*(out of 4 points) ** (out of 1 point)

Table 8

Summary of the Total Pretest and the Posttest Essay Results

	Pretest	Posttest
Participants	65	65
Mean	3.84	5.62
SD	1.98	2.97
Skewness	1.10	.673
Kurtosis	3.75	.831

Total Scores for Pre and Post Tests

Total test score (multiple choice and essay together) was 6.38 (SD = 3.05) on the pretest, with a posttest mean of 9.06 (SD = 4.19). Below are three histograms showing total scores for pretest, posttest, and achievement gain (posttest – pretest) respectively.

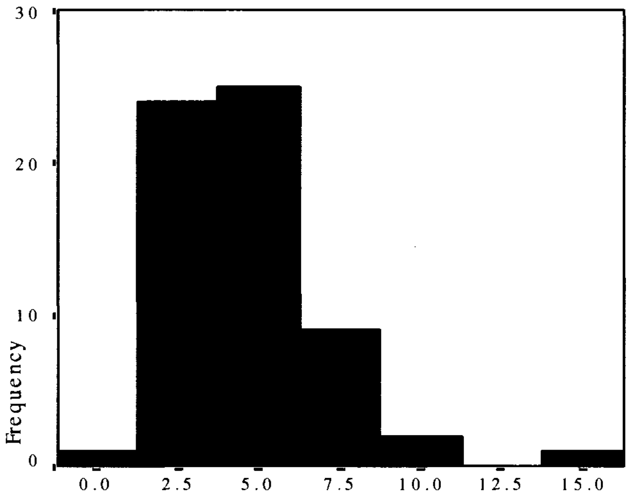


Figure 4. Histogram that represents total scores for pretest on science achievement.

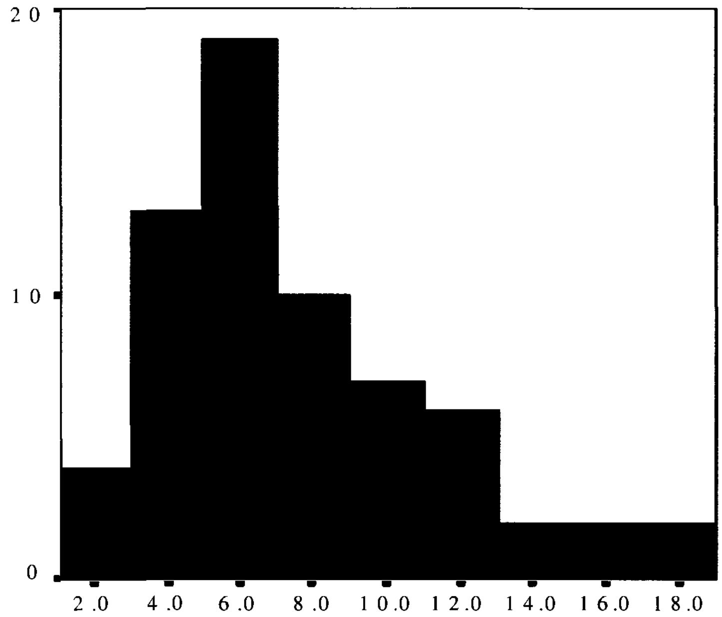


Figure 5. Histogram that represents total scores for posttest on science achievement.

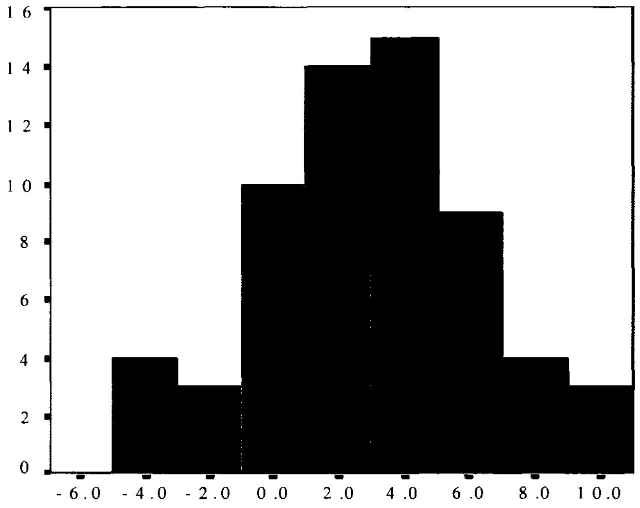


Figure 6. Histogram that represents achievement gain scores on science achievement.

Learning Styles Instrument

The Index of Learning Styles (ILS) consisted of 44 questions. Each question had two possible answers that reflect students' preferences within the Felder-Soloman (1994) model. For example:

1. I understand something better after I
   a) try it out.
   b) think it through.

There are eight dimensions to the Index of learning Styles. The score on each dimension, or model, ranges from 0-11, and the difference between scores for two related dimensions (e.g. Visual score – Verbal score) reflect the student's learning style (Zywno & Waalen, 2002).

VIS | **VRB**
11a 9a 7a 5a 3a 1a | 1b 3b 5b 7b 9b 11b

Participants who have a difference score of 1-3 are considered balanced on the two dimensions of the learning style scale. Participants with a difference score of 5-7 have a moderate preference for one dimension of the scale. Finally, participants with difference scores of 9-11 have a very strong preference for one dimension.

To make inferential statistics easier to run and interpret, the scoring system was modified from Felder's and Soloman (1994) difference score with an absolute value as explained above to a directional difference score. In other words, the researcher used a scale from -11 to +11 for each of the four combined dimensions: (a) Active/Reflective, (b) Sensing/Intuitive, (c) Visual/Verbal, and (d) Sequential/Global. Using the previous example Visual/Verbal as one dimension, participants who have a score of -1 to -3 are considered to have a weak preference for visual learning (as opposed to verbal learning). Participants who score between -5 and -7 have a moderate preference on visual learning style scale. Lastly, participants with scores of -9 to -11 have a very strong preference for the visual learning. The same thing can be said about the verbal side if the scores are positive. Hence, participants who have a score of 1-3 are considered to have a weak preference for verbal learning, participants who have a score of 5-7 are considered moderately verbal learners, and participants who have a score of 9-11 are considered strong verbal learners.

VIS | VER
-11 -9 -7 -5 -3 -1 | +1 +3 +5 +7 +9 +11

Results for the Active/Reflective continuum showed an overall mean of -1.86 (SD = 3.82), n = 67. Scores ranged from -11 (strongest active) to 7 (moderately reflective), and a reasonably normal distribution.

Results for the Sensing/Intuitive continuum showed an overall mean of -3.55 (SD = 3.99), n = 67. Scores ranged from -11 (strongest sensing) to 7 (moderately intuitive), and a roughly normal distribution.

Results for the Visual/Verbal continuum showed an overall mean of -4.55 (SD = 3.77), n = 67. Scores ranged from -11 (strongest visual) to 5 (moderately verbal), and a normal distribution.

Results for the Sequential/Global continuum showed an overall mean of -2.49 (SD = 3.80), n = 67. Scores ranged from -11 (strongest sequential) to 7 (moderately global), and a normal distribution.

Preservice elementary teachers' learning styles obtained from this study is further discussed. Table 9 shows the perservice elementary teachers' learning styles preferences which tend to be active, visual, sensing, and sequential. These preferences are consistent with an activity-based classroom environment with an emphasis on hands-on investigations and computer simulations as used in the course, which means that the course was designed to accommodate a wide range of students' learning styles. It is interesting to note that although whiteboard discussions take place in the course, the students report preferring visual over verbal.

Table 9

Preservice Elementary Teachers' learning styles

Groups	Preservice teachers (%)	Learning Styles	Description
Processing	n = 50, 75%	Active	Active students prefer to try things out and work in groups. Each member in the group take turns explaining what he/she might have learned. They like to guess on what answers might be required for questions that are going to be asked in a test.
	n = 16, 24%	Reflective	Reflective students on the contrary, do not tend to memorize the material. Also, they tend to work alone.
Perceptions	n = 54, 81%	Sensors	Sensing learners are concrete, practical, and try to solve things the easy way by using facts.
	n = 12, 18%	Intuitors	Intuitive learners like to be innovative and prefer theories and meanings.

(table continues)

Groups	Preservice teachers (%)	Learning Styles	Description
Input Modality	n = 57, 85%	Visual	Visual learners prefer to view pictures, diagrams, flow charts, films and other documentaries that enable them to remember the whole idea or subject
	n = 9, 13%	Verbal	Verbal learners tend to learn more out of written and spoken dialogues. more out of written and spoken dialogues.
Understanding	n = 50, 75%	Sequential	Sequential students are linear, and learn through logical and orderly small steps so they can relate the subject matter to what they already know.
	n = 16, 24%	Global	Global students look at the big picture and get an overall overview.

Three histograms depicting scores for each of four learning styles dimensions, Figures 7 through 10 are shown.

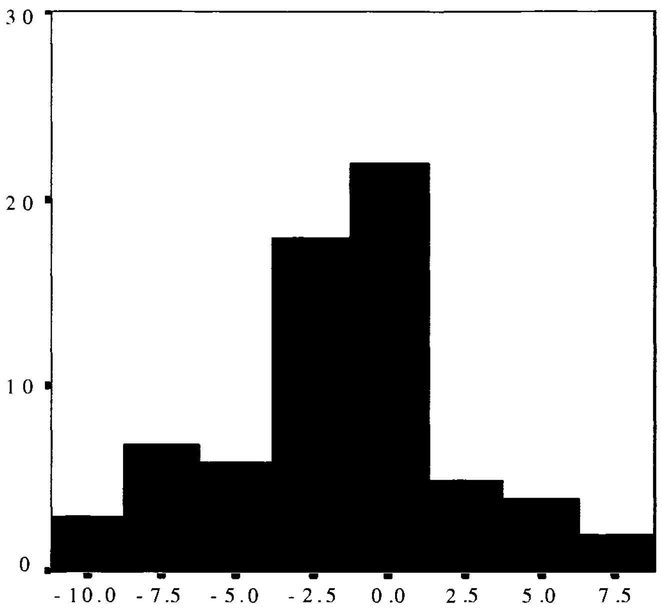


Figure 7. Histogram represents learning style dimension Active/Reflective (-11 to +11).

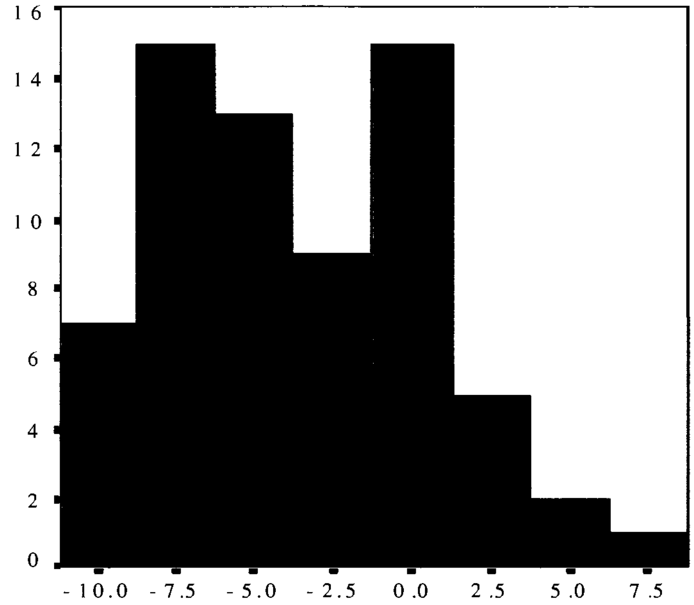


Figure 8. Histogram represents learning style dimension Sensing/Intuitive (-11 to +11).

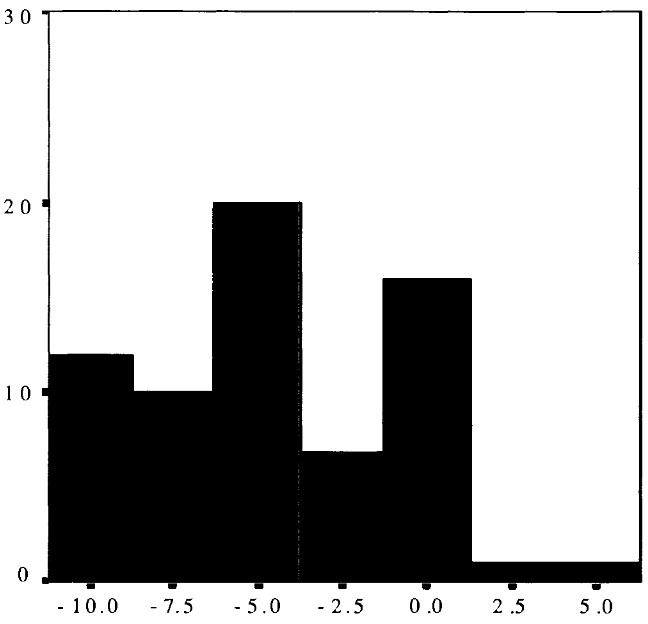


Figure 9. Histogram represents learning style dimension Visual/Verbal (-11 to +11).

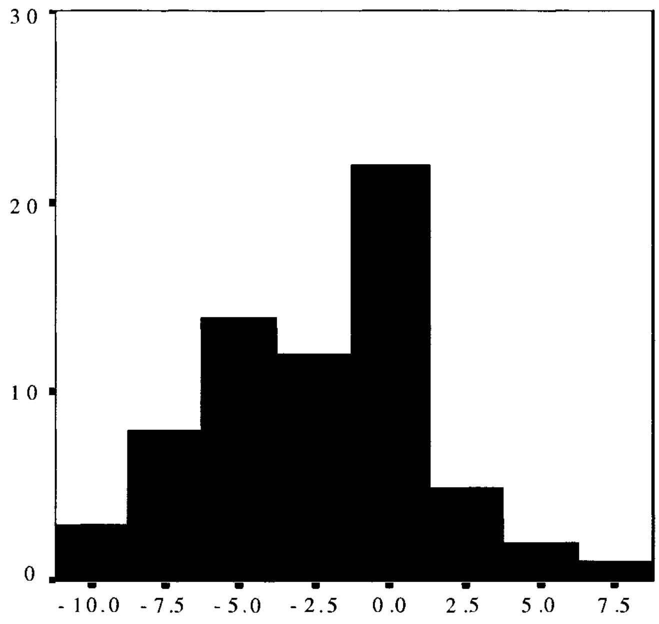


Figure 10. Histogram represents learning style dimension Sequential/Global (-11 to +11)

Inferential Analyses

All inferential analysis reported here were carried out using a linear regression approach. Regression is used to test for a relationship between one or more independent variables and a dependent variable. In this analysis, gain scores were used to capture the impact of the students' performance during the study.

Research Question 1: Does learning Style Affect Preservice Elementary Science Teachers' Conceptual Understanding of the Particulate Nature of Matter in a Science Class Which Uses Hands-on Learning Integrated with Computer Based Simulated Activities?

Learning style dimensions. A simple linear regression was calculated predicting subjects' achievement gain based on students' learning style score along the continuum Active/Reflective. A non-significant regression equation was found (F (1, 60) = .596, p > .05), suggesting that there was no significant linear relationship between students' learning style (Active/Reflective) and their science achievement gain.

A simple linear regression was calculated predicting subjects' achievement gain based on students' learning style score along the continuum Sensing/Intuitive. The regression equation was not significant (F (1, 60) = .005, p > .05), suggesting that there was no significant linear relationship between students' learning style (Sensing/Intuitive) and their science achievement gain. An examination of the scatter plot provided evidence that there was also no nonlinear relationship.

A simple linear regression was calculated predicting subjects' achievement gain based on students' learning style score along the continuum Visual/Verbal. The regression equation was not significant (F (1, 60) = .001, p > .05), suggesting that there was no significant linear relationship between students' learning style (Visual/Verbal) and their science achievement gain. An examination of the scatter plot provided evidence that there was no nonlinear relationship either.

A simple linear regression was calculated predicting subjects' achievement gain based on students' learning style score along the continuum Sequential/Global. The regression equation was not significant (F (1, 60) = .469, p > .05), suggesting that there was no significant linear relationship between students' learning style Sequential/Global and their science achievement gain. An examination of the scatter plot provided evidence that there was no nonlinear relationship either.

Overall. A multiple linear regression was calculated predicting subjects' achievement gain scores based on students' learning styles, entering in all 4 dimensions at the same time. The regression equation was not significant (F (5, 57) = .279, p > .05). Thus, learning styles as a group cannot be used to predict students' achievement gain.

Research Question 2: Is Preservice Elementary Majors' Science Learning in a Course Using Hands-on Learning Integrated with Computer-Based Simulations Related to their Attitude Towards Science?

A simple linear regression was calculated predicting subjects' achievement gain based on students' attitude. The regression equation was not significant (F (1, 62) = .612, p > .05), suggesting that there was no significant linear relationship between students' attitude towards science and their science achievement gain. An examination of the scatter plot provided evidence that there was also no nonlinear relationship.

Research Question 3: Is Preservice Elementary Teachers' Achievement Gain Scores Affected by Attitude and Learning Styles?

A multiple linear regression was calculated predicting subjects' achievement gain scores based on students' attitude toward science and their scores on each of the 4 dimensions of learning styles (Sequential/Global, Active/Reflective, Visual/Verbal, and Sensing/Intuitive). The regression equation was not significant (F (5, 55) = .362, p > .05). Attitude and the four learning styles dimensions together cannot be used to predict students' achievement gain. An examination of the scatter plot provided evidence that there was no nonlinear relationship.

A multiple linear regression was calculated predicting subjects' achievement gain scores based on students' attitude average and their learning style Active/Reflective. The regression equation was not significant (F (2, 58) = .652, p > .05). Neither attitude score nor Active/Reflective learning style scores can be used to predict students' achievement gain. An examination of the scatter plot provided evidence that there was no nonlinear relationship either.

A multiple linear regression was calculated predicting subjects' achievement gain scores based on students' attitude average and their Sensing/Intuitive learning style. The regression equation was not significant (F (2, 58) = .343, p > .05). Neither attitude nor sensing/intuitive learning style score can be used to predict students' achievement gain. An examination of the scatter plot provided evidence that there was no nonlinear relationship.

A multiple linear regression was calculated predicting subjects' achievement gain scores based on students' attitude average and their learning style Visual/Verbal. The regression equation was not significant (F (2, 58) = .326, p > .05). Neither attitude nor Visual/Verbal learning styles can be used to predict students' achievement gain. An examination of the scatter plot provided evidence that there was also no nonlinear relationship.

A multiple linear regression was calculated predicting subjects' achievement gain scores based on students' attitude average and their learning style Sequential/Global. The regression equation was not significant (F (2, 58) = .527, p > .05). Neither attitude average score nor Sequential/Global learning styles can be used to predict students' achievement gain. An examination of the scatter plot provided evidence that there was no nonlinear relationship either.

Research Question 4: Were Preservice Elementary Teachers' Science Misconceptions Dissipated Over the Course of this Study?

To answer the fourth question, the researcher compared pretest essay to posttest essay answers for a sample of students. Students' answers on the pre/post achievement test were categorized according to their class sections [SAJ, SBJ, and SCH (A, B, and C)] to establish consensus on how each section performed, knowing that the three sections are taught by two different instructors. Questions 4 and 5 were chosen based on their difficulty for students; they had the lowest amount of correct answers. The idea was to identify preservice elementary teachers' science conceptions and misconceptions and look for patterns.

The answers to question 5, which was the hardest for the students, were categorized individually. Then the answers were grouped to establish a rationale that can be used to shed light on ways to remedy the chronic misconceptions among preservice elementary teachers. A coding guide is used to measure the understanding for these teachers as follows: no comprehension, little comprehension, fair comprehension, complete comprehension, and scientific misconception shown in Table 10.

Table 10

Coding Guide for Students' Understanding of Science Concepts

Comprehension	Codes
No comprehension	No answer "I do not know" "I just guessed" "I just thought this way" Wrong answer
Little comprehension	Answers that include some applicable scientific concepts.
Fair comprehension	Answers that include a great deal of applicable scientific concepts but not all of them.
Complete comprehension	Answers that include a clear understanding of the scientific component
Scientific Misconception	Answers that do not match those of currently accepted scientific knowledge

Analyses for Answers for Questions 4 and 5 on the Achievement Science Test

The majority of the students did not do well in answering question 4 and 5 on the achievement test. Five students were selected for question 4 to provide the reader with an insight on how preservice elementary teachers formulated their reasoning on both the pretest and posttests essay answers. Question 5 on the other hand, was the hardest question among the students, thus the researcher selected all students to provide the reader with an insight on how preservice elementary teachers formulated their reasoning on both the pretest and posttests essay answers. Also the researcher addressed some of the misconceptions that preservice elementary teachers have provided in their answers. Additionally, while some students did well on the multiple choices answer with as little reasoning on the essay part, others persisted on the same misconception on both multiple choice tests, which reflected rooted misconceptions they possessed. The researcher grouped, analyzed and, compared the whole sample in all 3 sections.

Question#4

4. Consider three samples of water in three phases. The first is solid water (ice) at 0°C, the second is liquid water at 24°C, and the third is gaseous water at 100°C. The water molecules in the liquid phase __________ the water molecules in the gaseous phase.

A. move faster than
B. move slower than
C. move at the same speed as
D. move more randomly than
E. travel in the same direction as

Please elaborate and justify your reasoning? Identify any assumptions you are making.

Table 11 gives students' multiple choice and essay answers for this question on both pretest and posttest. Note that the correct multiple choice answer is B. A fully-flushed out essay answer can be found in Chapter 3. Participant SAJ6 began with a scientific misconception on both the pretest multiple choice question and essay answer. However, he/she chose the correct multiple choice response at posttest and had a correct but incomplete essay answer. Their posttest is much more accurate. Participant SAJ18 and SAJ22 showed little comprehension on both the pre-and post essay answers with a correct answer to the multiple choice question on the posttest. He/she acquired some understanding of the question at the end of the course. Participant SAJ21's essay answer on both the pre-and posttest reflect no comprehension of the subject matter, and perhaps show a misconception. His/her multiple choice answers were incorrect on both the pretest and posttest. Participant SAJ28's answer on the pretest essay "there is more substance to move & its easier to move water than gas" was not clear and could easily be considered a misconception. He/she stressed the word "move" and ignored the words "slow/fast" in the main question. Therefore, SAJ28 may have incorrect science knowledge about phase change and incorrect scientific terminologies. On the other hand, at posttest he/she chose the correct answer for the multiple choice question. His/her explanation was, "gases all so spread out they have few collisions + can move around more. The more heat is involved, the faster particles can move". He/she gave a better answer than on the pretest, utilizing the scientific term "heat" and "collisions" that might have been learned in the physical science class. However, he/she also used the incorrect conceptual answer "few collisions" instead of using "more collisions" in reference to gas movement at a higher temperature.

Table 11, also gives two students' multiple choice and essay answers on both the pretest and posttest for group SCH. Note that the correct multiple choice answer is B. Participant SCH9 showed little comprehension on both the pretest and posttest essay answer. Meanwhile, the same participant chose B--the right answer–on both the pre and post multiple choice item. This shows that his/her reasoning ability and explanation of the open ended answer were low. On the other hand, SCH12's answer had a scientific misconception (e.g., the molecules in the gaseous phase weigh less).

Table 11

Pretest and Posttest Multiple Choice Answers With Pretest and Posttest Essay Answers for the Groups SAJ and SCH

ID#	PreMCA	Pre Open Ended	PostMCA	Post Open Ended
SAJ6	A	B/C liquid molecules move faster than gas molecules	B	B/C the higher the temp. the more fast the particles move
SAJ18	A	I assumed that it would be quicker to melt a piece of ice rather than turning the ice and water into gas	B	It takes liquid more time to turn into a gas
SAJ21	A	They are more dense which= more mass to move gas kind of "floats"	A	The liquid particles glide over each other & move but gas particles are kind of just slowly floating around

(tables continues)

ID#	PreMCA	Pre Open Ended	PostMCA	Post Open Ended
SAJ22	A	I thought the colder the substance, the faster the molecules move	B	Solid particles move the slowest and gas particles move the fastest. Liquid particles move at a rate between the two
SAJ28	A	There is more substance to move & its easier to move water than gas	B	Gases all so spread out they have few collisions + can move around more. The more heat is involved, the faster particles can move
SCH9	B	Molecules speed up with temperature so ice would be the slowest, then water, then gas.	B	Gases move the fastest then liquids then solids
SCH12	B	The molecules in the gaseous phase weigh less so it would make sense that they would move quicker	B	Gas molecules always move the fastest

Question#5

5. When water is vaporized, it is changed to
   A. hydrogen and oxygen
   B. hydrogen only
   C. gaseous water
   D. air, hydrogen, and oxygen
   E. oxygen only

Please elaborate and justify your reasoning? Identify any assumptions you are making.

Table 12 gives students' multiple choice and essay answers on both pretest and posttest. Note that the correct multiple choice answer is C. A fully-flushed out essay answer can be found in Chapter 3. The majority of the participants in section SAJ did not demonstrate significant comprehension in answering question #5. For instance, participant SAJ2 chose D for the posttest multiple choice question, which was the wrong answer. His/her reasoning was: "evaporates, creating steam or condensation." It seems like he/she equates the process of making evaporation and steam to the process of condensation, which is a misconception. Since condensation is the opposite of evaporation. Evaporation and condensation are both related to a quantity named the "latent heat." However, the D answer on the multiple choice posttest question contains, in addition to "air," "hydrogen," and "oxygen." If the student assumes that air, hydrogen and oxygen are part of the evaporation or the condensation process, this would make his answer a misconception because water does not break down to its elements, hydrogen and oxygen, by boiling and evaporation.

Limited comprehension of the phase change concept was shown in many different answers. For example, participant SAJ4 chose D for the multiple choice question giving as the reason "CO_2 = Oxygen." There is no meaningful connection between his/her selected answer and the explanation provided. It is difficult to try to decipher what is going on here. It could be a simple error, a typo where he/she added an extra C next to O_2. But it could also signal a misconception if the participant meant to equalize carbon dioxide with oxygen.

Participant SAJ5 had the correct answer C on the posttest, but his/her explanation was that "particles cannot split apart." If this participant believes that molecules cannot be split, then one would think that SAJ5 has missed the whole concept of reactions (chemical changes), as well as splitting of molecules, atoms and subatomic particles. Perhaps this student used the term "particles" to represent gaseous water that was in their multiple choice answer. In this case, he/she may have meant that water molecules will not split upon heating to boiling down to its constituent atoms and make hydrogen and oxygen, which is correct, if poorly expressed.

A number of participants chose A as the answer on the posttest for question #5, which is the answer "hydrogen and oxygen". Their explanations for the answer were as follows:

SAJ6: Because hydrogen and oxygen make up water.

SAJ12: Goes into the air as hyd. & oxy.

SAJ14: This is what water is made of.

SAJ17: When water is vaporized it is changed into hydrogen & oxygen. It is no longer a liquid solid or gas. It turns into water vapor.

SAJ22: It is still the same thing, just in a different form.

SAJ26: The air particles don't break apart, they remain H_2O, just in a gas phase.

SAJ27: I just always have thought that.

SAJ7: Hydrogen + Oxygen by themselves would not make water.

The answers shown above may illustrate the participants failing to distinguish between the process of physical change and the process of chemical change. Though hydrogen and oxygen are the two main components of water, yet it is unlikely that bonds within water molecules can be broken in evaporation. Evaporation is a physical change, and its physical properties stay unchanged. Physical changes are about energy and states of matter, which can turn to a different phase (e.g. liquid, gas). Chemical change is the way in which bonds within water molecules are broken. For example, electrolysis is a way to break down water into Hydrogen and Oxygen. This can be done by running an electric current through water in the presence of a catalyst, such as sulfuric acid, in a voltameter that consists of platinum electrodes. The Anode and the Cathode are attached to a battery to produce a current. Bubbles start to appear in the two arms of the voltammeter. The Anode collects oxygen and the cathode arm collects hydrogen gas. The process of electrolysis is typically introduced in chemistry at the high school level. The participants failed to give an adequate explanatory construct of the process of water evaporation at the microscopic level. These students have misconceptions. Perhaps these participants are unaware of phase change. The students' wrong ideas may be influenced in unexpected ways by junior school or high school science teaching.

SAJ7, on the other hand, chose C (the right answer) on the posttest, but his explanation was that "Hydrogen and Oxygen by themselves would not make water." It is difficult to judge what this means only by analyzing his/her answer without talking to the person face-to-face. Perhaps he/she meant that choice A "hydrogen and oxygen" was not the right answer, and therefore he/she chose C for the right answer "gaseous water"? This is considered as a case of poor reasoning.

Table 12

Pretest and Posttest Multiple Choice Answers With Pretest and Posttest Essay Answers for the Group SAJ

ID#	PreMCA	Pre Open Ended	PostMCA	Post Open Ended
SAJ2	D	But I really don't know	D	Evaporates, creating steam or condensation
SAJ3	C	None	A	None
SAJ4	D	Just a guess because it is H_2O	D	CO_2 = Oxygen
SAJ5	A	I don't think it can change to "air" like in D, so I guessed A	C	Particles cannot split apart
SAJ6	A	B/C I kind of just picked this one.	A	B/C hydrogen & oxygen make up water
SAJ7	A	None	C	Hydrogen + Oxygen by themselves would not make water
SAJ8	D	It turns into those three	A	The molecules are just being vaporized they are being broken apart
SAJ9	A	I think it's changed to hydrogen and oxygen but I really have no clue at all	C	B/C that's the next state
SAJ10	B	Not really sure	C	Water is changed to water vapor after it is boiled or when it reaches boiling point
SAJ11	D	I really don't know why I chose this it just seemed like a good answer	D	It is vaporized into all 3 because it separates them
SAJ12	E	It goes into the air	A	Goes into the air as hyd. & oxy.
SAJ13	A	?	D	None

(table continues)

ID#	PreMCA	Pre Open Ended	PostMCA	Post Open Ended
SAJ14	A	The parts wouldn't change	A	This is what water is made of.
SAJ15	A	H_2O= hydrogen & oxygen	C	The molecules don't change, they just change state
SAJ16	B	It is changed only to hydrogen because the oxygen goes out of the water and leaves into the air	C	The water doesn't change, it stays water just in a gaseous state
SAJ17	A	None	A	When water is vaporized it is changed into hydrogen & oxygen. It is no longer a liquid solid or gas. It turns into water vapor.
SAJ18	A	None	D	None
SAJ19	D	Not sure, I just guessed	C	It's a gas
SAJ20	A	Releases into air as oxygen & hydrogen	A	Both gasses
SAJ21	C	?	A	It's turned to gas
SAJ22	A	The chemicals don't change when the substance changes	A	It is still the same thing, just in a different form
SAJ23	A	The molecules just separate	C	Water just changes states
SAJ24	A	It would turn into hydrogen & oxygen because that is what water is made of	C	It is still water, just vaporized
SAJ25	D	None	D	Same, just in different state
SAJ26	A	The molecules would break apart from each other	A	The air particles don't break apart, they remain H_2O, just in a gas phase
SAJ27	D	None	A	I just always have thought that
SAJ28	C	There's more oxygen, but water molecules still present making it more gaseous	C	It's heated & nothing is removed, it's still water – diff state = vapor

Table 13 describes, for section SAJ, the way misconceptions were grouped, the number of students in each group, their percentage, and their type of answer. Many preservice elementary teachers held misconceptions about phase change as shown in question 5. In section SAJ, multiple choice answers, 40.7% (category 1) held the misconception that water breaks down to hydrogen and oxygen when boiled. Twenty-two percent (category 2) thought that water changes to air, hydrogen, and oxygen when evaporated. Fifty-six percent of them changed their wrong pretest answers to another wrong answer on the posttest. Thirty-three percent of the students seemed to change their wrong pretest answer to a right answer on the posttest. Two students (7.4%) went from right answer on the pretest to the wrong answer on the posttest. Finally, only 1 student (3.7%) answered correctly on both pretest and posttest. Essay answers revealed considerable inaccurate scientific knowledge. Many responses included scientific information such as that water is composed of two main elements -- hydrogen and oxygen -- with a 2 to 1 ratio, which represent the use of a scientific term. However, misconceptions also showed up when the process of evaporating water is said to break down its molecules into its constituent elements. This problem also, could be related to the limited science knowledge and perhaps to the memorization to science concepts.

Table 13

Summary of Grouped Misconceptions Based on Multiple Choice Questions in Section SAJ

Group SAJ on MCQ	Total # out of 27 students	Percentages %	Type of answer on post test
Category 1 Misconceptions*	11	40.7	Water breaks down to hydrogen and oxygen
Category 2 Misconception*	6	22	Air, hydrogen, and oxygen
Category 3 Misconception*	0	0	Oxygen only or Hydrogen only
Misconceptions Wrong to Wrong	15	56	Switched from A or any wrong answer A, D, and E
Switched to the right answer. Wrong to Right	9	33	Any wrong answer to the right answer C
Switched to wrong answer. Right to wrong	2	7.4	From the right answer C to any wrong answer
Stable Right to Right	1	3.7	No change in the right answer

*Answers on posttest only

Table 14 gives students' multiple choice and essay answers on both pretest and posttest for section SBJ. Note that the correct multiple choice answer is C. A fully-flushed out essay answer can be found in Chapter 3. There is additional evidence in the participants' answers that they faced difficulties in understanding the microscopic and macroscopic properties of matter and the phase changes that take place during the process of evaporating water. The majority of the participants in this section did not demonstrate significant comprehension in answering question 5. They have exhibited limited, or no understanding of the particulate nature of matter. Some of the students chose the correct multiple choice response on the posttest, but showed little or no comprehension, or left incomplete answers, on their essay (e.g., SBJ 5, 6, 7, 8, 12, 17, 18, 19, 20, 22, 23, and 25).

The misconception about water molecules breaking into Hydrogen and Oxygen upon evaporation continued among participants in section SBJ. For instance, some participants chose A and D as the answers for the posttest multiple choice question#5 "when water is vaporized, it is changed to," which is the answer "hydrogen and oxygen" or "air, hydrogen and oxygen." Their explanations for the answer were as follows:

SBJ2: Water is made of hydrogen and Oxygen.

SBJ3: It doesn't change the types of particles, it just changes the arrangement.

SBJ4: It breaks up when it changes state which makes it separate out from being H_2O it goes to H_2 & O.

SBJ9: Water is H_2=hydrogen O=oxygen.

SBJ13: It separates out.

SBJ15: The particles break up & turn into separate things.

SBJ26: They form when water turns to the gaseous state.

These participants seem not to be distinguishing physical from chemical change. These participants failed to give an adequate explanatory construct of the process of boiling water into gaseous water with the original molecules that possess the characteristics of water. Breaking intramolecular bonds in water –bonds hold atoms in a water molecule--is a chemical change, which requires much more energy than breaking intermolecular bonds--bonds between water molecules--,which results in a physical change. Participants were unable to differentiate between "hydrogen and oxygen" in the answer A, and "gaseous water" in the answer C. Perhaps the term "gaseous water" was not one they had seen much previously. However, for students to be convinced that hydrogen and oxygen would be released in water's evaporation process is a significant scientific misconception.

Two participants chose E as an answer on the posttest --"Oxygen only." And their explanations for the answers were as follows:

> SBJ27: It will be hydrogen only because Oxygen can't be vaporized. (pretest)
>
> SBJ27: It turns into a gas stage such as oxygen. (posttest)
>
> SBJ28: Water is 2 parts Hydrogen and one part Oxygen (pretest).
>
> SBJ28: If it were evaporated to H_2O and not to Oxygen the vapor would be very flammable.

Both participants SBJ27 and SBJ28 had no significant comprehension of phase change according to both their pretest and posttest answer. While participant SBJ27 chose B "Hydrogen only" on the pretest multiple choice question and the answer E "Oxygen only" on the posttest, participant SBJ28 chose the answer A "Hydrogen and Oxygen" on the pretest and the answer E "Oxygen only" on the posttest, both of which are wrong answers. It is important to address these types of profound misconceptions strongly in the chemistry curriculum. Both participants appear to hold considerable scientific misconceptions regarding the components and evaporation of water. If participant SBJ28 meant that water vapor would be "flammable" according to his/her answer on the posttest, this would signal an even greater reason to be concerned.

Table 14

Pretest and Posttest Multiple Choice Answers With Pretest and Posttest Essay Answers for the Group SBJ

ID#	PreMCA	Pre Open Ended	PostMCA	Post Open Ended
SBJ2	A	It is made of hydrogen & oxygen	A	Water is made of hydrogen & oxygen
SBJ3	A	It doesn't change what it's made of	A	It doesn't change the types of particles, it just changes the arrangement
SBJ4	A	Hydrogen & oxygen make up air	A	It breaks up when it changes state which makes it separate out from being H_2O it goes to H_2 & O
SBJ5	A	Because water is made up of hydrogen and oxygen	C	Just changes state
SBJ6	A	They separate	C	None
SBJ7	A	Because that is what water is made up of	C	Changes into a gas state
SBJ8	E	Oxygen is what evaporates, hydrogen is unable to	C	The water has become vapor, but is still composed of water just more gaseous
SBJ9	A	I would it assume since it's H_2O it would change to both	D	Water is H_2=hydrogen O=oxygen
SBJ12	A	It still has the same parts as water: Hydrogen and Oxygen- however it is just in a different form	C	It undergoes a physical change of states however it still remains water

(table continues)

ID#	PreMCA	Pre Open Ended	PostMCA	Post Open Ended
SBJ13	D	It separates	A	It separates out
SBJ14	A	That's what its made of	D	None
SBJ15	D	All 3 of them come from the vapor b/c it goes to them	D	The particles break up & turn into separate things
SBJ16	A	I don't know, because that's what water is made up of, H2O	A	None
SBJ17	A	If it was any of the other choices it would no longer be water. I am assuming that H_2O in vapor form is the same as gaseous water	C	Evaporation is a physical change. Chemical properties don't change.
SBJ18	A	When its vaporized it separates H_2O so it would stay separate	C	It is still water its just in a gaseous state. It doesn't split into Hydrogen and Oxygen. It stays together
SBJ19	A	It separates and the steam you see is oxygen	C	It is only a physical change so the chemical form stays the same
SBJ20	A	Water is made up of hydrogen and oxygen (H_2O=water, H=hydrogen and O=Oxygen)	C	The particles don't divide when water becomes a gas, they just become more widely spread apart
SBJ21	A	None	A	None
SBJ22	A	Because water = H_2O	C	Particles are not separated
SBJ23	A	The molecules break up and when separate they will be hydrogen and oxygen	C	It doesn't break up
SBJ24	A	H_2O is water which made of hydrogen & oxygen	C	The 2 particles do not fully separate

(table continues)

ID#	PreMCA	Pre Open Ended	PostMCA	Post Open Ended
SBJ25	D	It separates into the air, but keeps its parts or it would not be water	C	b/c it is still water, but in a different state
SBJ26	D	Water vaporizes which then goes into the air creating hydrogen and oxygen	A	They form when water turns to the gaseous state
SBJ27	B	It will be hydrogen only because Oxygen can't be vaporized	E	It turns into a gas stage such as oxygen
SBJ28	A	Water is 2 parts Hydrogen and one part Oxygen.	E	If it were evaporated to H_2O and not to Oxygen the vapor would be very flammable.

Table 15 describes the way misconceptions were grouped, the number of students in the group, their percentage, and their type of answer for section SBJ.

Table 15

Summary of Grouped Misconceptions Based on Multiple Choice Questions in Section SBJ

Group SBJ on MCQ	Total # out of 26 students	Percentages %	Type of answer
Category 1 Misconceptions*	10	38.5	Water breaks down to hydrogen and oxygen
Category 2 Misconceptions*	0	0	
Category 3 Misconceptions*	2	7.6	Oxygen only
Misconceptions Wrong to Wrong	12	46	Switched from A answer to either A, D, and E
Switched to the right answer. Wrong to Right	13	50	Any wrong answer to C
Switched to Wrong Answer. Right to Wrong	0	0	
Stable Right to Right	0	0	No Change

*Answers on posttest only

Table 16 gives students' multiple choice and essay answers on both pretest and posttest for section SCH. Note that the correct multiple choice answer is C. A fully-flushed out essay answer can be found in Chapter 3. This section has the smallest number of participants, 13. The majority of the participants in this section SCH did not demonstrate significant comprehension in answering question #5. Only 2 participants chose C as the right answer on the posttest, but they reflected little or no comprehension, and as well as possible misconceptions, in their essay answers. The rest of the participants chose A, except for two students. They chose B and E as their multiple choice answer on the posttest, which are "Hydrogen and Oxygen" and "Oxygen only" respectively. No considerable differences on the reasoning that was provided in essay answers to the essay questions from the other two sections SAJ and SBJ were detected in section SCH. For example, the reasoning for choosing A or E on the posttest essay answers was as follows:

SCH3: All other particles evaporated.

SCH4: These are hydrogen & Oxygen.the elements that makes up water in the gaseous stage it is

SCH7: The molecules separate when evaporated.

SCH9: Hydrogen & Oxygen is what the water is made of. it would not lose anything when it changed phases.

SCH10: It evaporated in the air & some of the molecules are gone but it is still hydrogen & oxygen.

SCH12: H_2O →breaks down into its separate molecules 2 hydrogen and 1 oxygen.

SCH14: These are its components.

Like the other two sections, this section seems to have many participants with limited scientific comprehension on question #5. Evidence to that showed in several multiple choice and essay answers students provided. Some of the students answered A, "hydrogen and oxygen," on the pretest as well as on the posttest (wrong answer). This may signal persistence on the same misconception that was deeply rooted in previous science learning. It could also signal that these students were not motivated to articulate the correct the scientific explanation when asked for their reasoning. In addition, they might not be familiar with the type of chemistry questions on the assessment sheet. Other participants, such as SCH9 had A, the "wrong answer" on both the pretest and on the posttest. However, he/she gave a fair reasoning on the posttest essay answer by claiming that water evaporation is merely a phase change. Perhaps this student may have misread the right multiple choice answer.

Table 16

Pretest and Posttest Multiple Choice Answers With Pretest and Posttest Essay Answers for the Group SCH

ID#	PreMCA	Pre Open Ended	PostMCA	Post Open Ended
SCH1	C	It is gaseous water because the molecules are the exact same, they don't break apart into the different parts	C	The particles do not change
SCH3	A	Even though the water is vaporized the hydrogen & Oxygen is still there just not together making water	E	All other particles evaporated
SCH4	A	It is still water & hydrogen together = H_2O	A	These are the elements that makes up water in the gaseous stage it is hydrogen & Oxygen
SCH5	A	Water is made of hydrogen & oxygen	A	None

(table continues)

ID#	PreMCA	Pre Open Ended	PostMCA	Post Open Ended
SCH6	A	They separate into separate molecules H_2O = hydrogen & Oxygen	A	None
SCH7	D	Because some evaporates into air and are just becomes water vapor	A	The molecules separate when evaporated
SCH8	A	None	C	None
SCH9	A	Molecules stay the same but aren't bonded the same in the different states	A	Hydrogen & Oxygen is what the water is made of. it would not lose anything when it changed phases
SCH10	A	I just guessed "A" because I think both the hydrogen & oxygen would stay	A	It evaporated in the air & some of the molecules are gone but it is still hydrogen & oxygen
SCH11	None	None	C	This is because the particles stay the same but they are just moving faster and spreading throughout the air causing water vapor (gaseous water)
SCH12	A	H_2O is the chemical name for water so when it breaks down, the parts that are left are the atoms that make it up	A	H_2O →breaks down into its separate molecules 2 hydrogen and 1 oxygen
SCH13	A	My best guess, I am assuming H_2O would separate into hydrogen and oxygen	B	I guessed
SCH14	C	It remains water, but in a gaseous form	A	These are its components

Table 17 describes, for section SCH, the way misconceptions were grouped, the number of students in the group, their percentage, and their type of answer.

Table 17

Summary of Grouped Misconceptions Based on Multiple Choice Questions in Section SCH

Group SCH on MCQ Types of	Total # out of 13 students	Percentages %	Type of answer
Category 1 Misconceptions*	10	76.9	Water breaks down to hydrogen and oxygen
Category 2 Misconceptions*	0	0	
Category 3 Misconceptions*	1	7.6	Hydrogen only, Oxygen only
Misconceptions Wrong to Wrong	9	69.2	Switched from A or any wrong answer to either A, D, and E
Switched to the Right Answer. Wrong to Right	2	15.4	Any wrong answer to C
Switched to the Wrong Answer. Right to Wrong	0	0	
Stable Right to Right	1	7.7	No change

*Answers on posttest only

Table 18 sums up the way students in all three sections were grouped, the number of students, their percentage, and their answers' type. Evidence the participants' answers shows that they faced challenges in understanding chemistry concepts of the microscopic and macroscopic properties of matter and the phase changes that take place during the process of evaporating water. Overall, the participants did not demonstrate significant comprehension in answering question 5. They have exhibited limited, or no understanding of the particulate nature of matter. A large number of elementary teachers, 46.2 %, chose an answer that reflect a category 1 misconception–scientifically invalid concepts (SIC), such as, water breaks down to its constituents elements when heated or evaporated. Nine percent had category 2 misconceptions–perceived as logical (PAL) – such as, because air contains water; therefore, when water breaks down into its elements, it turns into air, hydrogen, and oxygen. Six percent exhibited category 3 or unexpected misconceptions–severe scientific misconception (SSM)--such as, water breaks down to one of its constituents when heated or evaporated. Fifty-four percent of students had wrong answers on both pretest on the posttest. Thirty-six percent seemed to change their wrong pretest answer to a right answer on the posttest. Two students (3%) changed the right answer on the pretest to the wrong answer on the posttest. Finally, only 2 students (3%) answered correctly on both pretest and posttest. Essay answers revealed considerable inaccurate scientific knowledge. Many responses included scientific information such as that water is composed of two main elements -- hydrogen and oxygen--with a 2 to 1 ratio, which represent the use of a scientific term. However, misconceptions also showed up when the process of evaporating water is said to break down its molecules into its constituent elements. Astonishing results noticed in this study are that some students changed their answers from the right answer on the pretest to the wrong answer on the posttest. It is possible that they were guessing the answers due to the lack of motivation when taking the assessment test. This problem also, could be related to the limited science knowledge and perhaps to the memorization to science concepts.

Table 18

Summary of Grouped Misconceptions Based on Multiple Choice Questions in All Sections, SAJ, SBJ, and SCH

Misconceptions in All Groups on MCQs	Total # out of 67 students	Percentages %	Type of answer on post test
Category 1 Misconceptions* or (SIC)	31	46.3	Water breaks down to hydrogen and oxygen
Category 2 Misconception* or (PAL)	6	9.0	Air, hydrogen, and oxygen
Category 3 Misconception* or (PAL)	4	6	Oxygen only or Hydrogen only
Misconceptions Wrong to Wrong	36	53.7	Switched from A or any wrong answer on the pretest to A, D, and E on the posttest
Switched to the Right Answer. Wrong to Right	24	35.8	Any wrong answer on the pretest to the right answer C on the posttest
Switched to wrong answer. Right to wrong	2	3	From the right answer C on the pretest to any wrong answer on the posttest
Stable Right to Right	2	3	No change in the right answer on both pretest and posttest

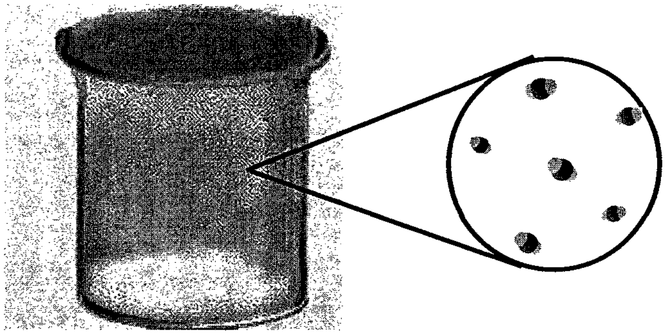
*Answers on posttest only

Graduate Students Achievement Test

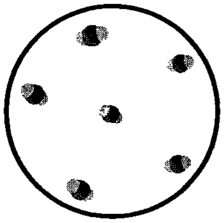
Five chemistry Ph.D. students from a major university in the south were selected to answer the achievement test. The test was given to them only one time. These students were recruited by a colleague who was among the five students selected for the study. All of them were doctoral students in the inorganic chemistry department. They were given the Science Achievement Instrument. In this section, results for question 2 and 4 will be presented because these are the questions that some Ph.D. students had some difficulty with. In addition, answers to question 5 will also be provided to compare the answers to the preservice elementary teachers' answers on the same question. Table 19 shows their answers to the multiple choice question and the essay answer for question 2 in the Science Achievement Instrument.

Question #2

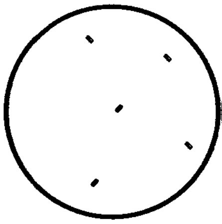
2. A magnified view of a sample of carbon dioxide (CO2) gas at a pressure of 1.0 atm is shown below.



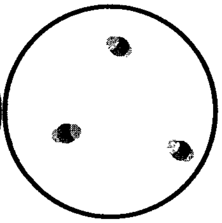
Which of the following diagrams best describes what you would "see" in the same area at a reduced pressure of 0.5 atm?



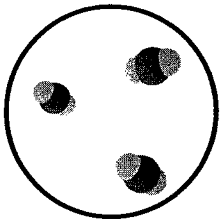
A.



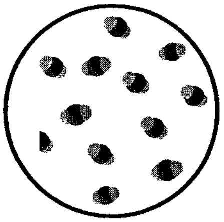
B.



C.



D.



E.

Please elaborate and justify your reasoning? Identify any assumptions you are making.

Table 19

Multiple Choice and Essay Answers for the Ph.D. Students on Question 2

Ph.D. Student	MCA	Open Ended Answers
#1	B	At reduced pressure, the molecules should be more disperse.
#2	C	Reduced pressure the distance between molecules will increase.
#3	C	The pressure is directly proportional to the amount of the substance so a lower pressure in the same volume would require either a lowered temp or a lower amount of material.
#4	C	With loss pressure, gas molecules have more freedom to move about and would want to separate.
#5	A	There would virtually be no change since CO_2 is still a gas and will be evenly dispersed in the beaker until a phase change.

Table 19 gives a students' multiple choice and essay answers. Note that the correct multiple choice answer is C. A fully-flushed out essay answer can be found in Chapter 3. A correct explanation would include: less pressure indicates that there are fewer particles collisions between carbon dioxide molecules and the walls of the container, but the chemical composition of the molecules would not change. The drop in pressure will allow the fewer molecules to spread out in the same amount of space. Students #1 and #5 did not give the right answer to the multiple choice question. Participant #1 gave an answer that talked about the dispersion of carbon dioxide molecules when pressure is reduced in the container, but did not fully explain the answer.

Therefore, participant #1 displayed little comprehension of the scientific concept. Meanwhile, participant #5 seems to have a misconception if he/she believes that reducing pressure would have no effect (e.g., “There would virtually be no change since CO_2 is still a gas”).

The other three students chose C as the correct answer for the multiple choice question. It appeared that the students’ answers to the essay part reflected fair comprehension of the scientific concept. Participant #3 provided extra information and used more elaborating chemical terms in his answer (e.g. “The pressure is directly proportional to the amount of the substance so a lower pressure in the same volume would require either a lowered temp or a lower amount of material”).

Question#4

4. Consider three samples of water in three phases. The first is solid water (ice) at 0°C, the second is liquid water at 24°C, and the third is gaseous water at 100°C. The water molecules in the liquid phase __________ the water molecules in the gaseous phase.

A. move faster than
B. move slower than
C. move at the same speed as
D. move more randomly than
E. travel in the same direction as

Please elaborate and justify your reasoning? Identify any assumptions you are making.

Table 20

Multiple Choice and Essay Answers for the Ph.D. Students on Question 4

Ph.D. Student	MCA	Open Ended Answers
#1	B	Temperature is a measure of average kinetic energy. As the temperature rises the kinetic energy increases.
#2	B	Molecules move slower because of the close pressure of other molecules. Motion is restricted.
#3	B	There are strong intermolecular interactions which limit the motion but more importantly the liquid is at a much lower temperature.
#4	B	The amount of thermal energy at 24 C Vs 100 C is much less correspondingly atoms move (transition), vibrate, and rotate less due to fewer accessible energy state.
#5	B	Gas molecules are not governed by intermolecular forces to the extent that liquid molecules are. Since gas molecules have less interaction they are free to disperse into the area they occupy.

A full answer to question 4 would include: as temperature increases, kinetic energy increases. Since kinetic energy is the energy associated with the motion of an object, higher kinetic energy indicates a faster speed. Consequently, a higher temperature also indicates a faster speed. Since the temperature of the water is lower than the temperature of the gas, the water molecules must be moving slower than the gas molecules.

Table 20 contains chemistry doctoral students' answers to question 4, which shows that all five students gave the right answers to the multiple choice question. It appears that all students' answers to the essay part reflected fair comprehension of the scientific concept. Student #2 seems to have little comprehension of the scientific concept (e.g., "Molecules move slower because of the close pressure of other molecules. Motion is restricted"). Perhaps this student could have mentioned the intermolecular and intramolecular forces that exist within and between the water molecules that might restrict water movement.

<u>Question#5</u>

5. When water is vaporized, it is changed to
   - A. hydrogen and oxygen
   - B. hydrogen only
   - **C. gaseous water**
   - D. air, hydrogen, and oxygen
   - E. oxygen only

Please elaborate and justify your reasoning? Identify any assumptions you are making.

Table 21 gives students' multiple choice and essay answers. Note that the correct multiple choice answer is C. A fully-flushed out essay answer can be found in Chapter 3. Table 21, which contains chemistry doctoral students' answers to question 5, shows that all five students gave the right answers to the multiple choice question. It appears that all students' answers to the essay part reflected fair comprehension of the scientific concept.

Table 21

Multiple Choice and Essay Answers for the Ph, D. Students on Question 5

Ph.D. Student	MCA	Open Ended Answer
#1	C	In gas phase, there is nothing to keep ions apart so you still have H_2O but in the gas phase...
#2	C	Matter is no destroyed but converted into different forms.
#3	C	Evaporation is a physical change. A, B ,D , E all represent chemical change.
#4	C	Vaporization refers to liquid going to gas. $H_2O\ (l) \rightarrow H_2O\ (g)$
#5	C	Vaporization is a phase change from liquid to gas.

Summary

In summary, preservice teachers' open-ended explanations on both the pretest and the posttest indicate an inability to establish a well-rounded reasoning, especially on the posttest. The inability of the preservice teachers to present a clear scientific answer in the pretest was not a big surprise, but the extent of problems remaining in the posttest is troubling. It is unlikely that elementary students rectify science misconceptions by enrolling in only one introductory physical science content course. The problem is the cycle of misconception will continue, because these elementary teachers are most likely going to teach science. However, it is worth to note that the lack of motivation on the students to complete the Assessment Science test and to do well must be considered.

Perservice elementary teachers' comprehension of chemical concepts in this study varied from no comprehension to fair comprehension, and included many misconceptions; no answer showed complete understanding of the concepts. Many of the preservice elementary teachers held misconception in answering question 5 (e.g., "When water is vaporized it is changed into hydrogen & oxygen. It is no longer a liquid solid or gas"). If not addressed in science content and methods courses, this could be a problem as this new generation of teachers goes out to teach.

The chemistry Ph.D. students, on the other hand, demonstrated higher comprehension in their answers than the answers provided by preservice elementary teachers, yet in some cases their answers fell into the categories of little to fair comprehension. They did not elaborate on the essay answers in a way that shows more understanding of the question. It is possible that the Ph.D. students thought that their answers were sufficient to be understood by another chemistry student. The researcher was not at the scene to further explain what was wanted. It was also expected that these students would use more scientific terminologies than would the preservice elementary students. They are chemistry majors, so they had taken many chemistry courses. Also, they chose chemistry majors because they perhaps found that science and chemistry are their favorite subjects that want to pursue as career. On the other hand, preservice elementary students did not choose science career. Instead, they chose to teach at the elementary level, which might include teaching science subject. Several Ph.D. students gave an inaccurate explanation to some of the questions in their essay answers, which could be viewed as evidence of a scientific misconception. This could mean that even chemistry student may not have done well because they have not been asked these types of questions in the past. The results may reveal lack of familiarity with this type of questioning and not necessarily a lack of understanding.

The most conspicuous conclusion that can be made from the data obtained from this study is that preservice elementary teachers did not show sound understanding of the concept of physical change. Their answers varied from no comprehension to fair comprehension, and included a variety of misconceptions. Several explanations might be considered as to why the chemistry concepts tested in the Science Achievement test were so challenging to preservice elementary teachers. First, learning of science concepts prior to taking this college physical science content course was not adequate or insufficient if they had taken any science or chemistry at junior year of high school. This was not the focus of this study, but it is a crucial period of time in which students should learn the right science. This could lead to the possibilites that (a) preservice elementary teachers did not learn the core basics of science and chemistry well in their years of school, especially the particulate nature of matter and atomic model including physical and chemical changes; (b) these students might have provided with unqualified and ineffective science teachers who taught science inadequately; and (c) they were instructed in a traditional way, and consequently did not use labs and other new scientific techniques that include computer technologies at the elementary level through high school.

Second, preservice elementary teachers may have considered that the science content was an unnecessary course to enable them to become a "generalist" at the elementary level. It is, however, a course that must be taken because it is a requirement for a teaching certificate. If this holds true, then it perhaps gave them the impression that science is a boring subject, which contains abstracts concepts that are very hard to learn. In addition, the science content course instructors have different teaching backgrounds, and little direct teaching experience with the PSET curriculum. Hence, this might have lead some students to utilize the class settings to their advantage to improvise techniques and pass the course with limited superficial science knowledge. Data from the attitude instrument shows that these elementary preservice teachers have a less than positive attitude towards science subjects. This might have hindered their learning and limited their elaboration in the essay answers.

CHAPTER 5

ANALYSIS

This chapter provides a summary of the findings and discussion for each instrument and for each research question. Following the summary are sections detailing implications of the study and suggestions for future research.

This study investigated the effect of learning styles and attitude toward science on preservice science teacher's conceptual understanding of the nature of matter in a simulation-based learning environment. Pre-service elementary science teachers in this study were enrolled in an introductory physical science course that integrates inquiry-based instruction with computer simulations. Following the literature review of learning style given in Chapter 2, it seems reasonable that students with certain learning styles would benefit more than others. Further, it seems reasonable that those with better attitudes towards science would learn more.

Student Achievement

The preservice elementary teachers in this study had relatively low comprehension of science material involved as shown on the science achievement instrument. There was only modest progression in the presrvice teachers' conceptual understanding between pretest and posttest. For the 6 multiple choice questions, the pretest mean was 2.36 out of 6 as compared to the posttest mean of 3.45 ($\underline{SD} = 1.53$). For the essay questions, the pretest mean was 3.84 out of 21 as compared to 5.6 at the posttest.

The results above suggest students had a relatively low positive achievement gain on the posttest after taking a physical science content course for eight weeks. Perhaps this is due to the complexity of the chemistry or the conceptually rich science concepts in the physical science content course taken by preservice teachers. For instance, on the pretest multiple choice, 7% preservice science teachers answered question 5 correctly. This number jumped up to 40% on the posttest. On the pretest essay part for the same question, 41.5% did not comprehend the answer, 56.9% showed little comprehension, and only 1.5% had little to fair comprehension. On the posttest on the other hand, 23.1% participants had no comprehension, 63.1% participants had little comprehension, 12.3% participants had little to fair comprehension, and 1.5% participants had little to fair comprehension. This is an improvement, but reflects relatively low concept attainment following instruction. It is important to note that the PSET curriculum introduces physics and chemistry ideas with the focus on Energy and Interactions. As a result, physical and chemical changes were introduced within this prospective. Therefore, there could be some degree of mismatch between course instruction and the assessment used within the study.

The inadequate comprehension of scientific concepts addressed in the physical science content course is further shown by answers on question 6. Question 6 was given twice to the students as one of twenty questions, called the PSET diagnostic test, at the beginning and end of the course. Question 6 was also used in the adapted science achievement instrument to establish a base as to whether preservice teachers understood the previous question in the instrument, which is based on a similar water vaporization concept. Instead of explaining the answer, respondents can predict one of five diagrams that represent the phase of water evaporation and confirm their answer by choosing whether they are sure or not.

Results of preservice elementary teachers on question 6 on the pretest showed 15.4% participants chose the right answer and 33.8% gave the right answer on the posttest. To compare preservice teachers' answers on both questions 5 and 6 on the posttest, 23% of the participants did not choose the right answer on question 5, while 66% of the participants opted for a wrong answer on question 6. Note that the two questions are closely related to the water evaporation, but both were laid out differently on the science achievement test.

Given that the preservice elementary teachers took question 6 before the course, then took the course, and finally took the same question for this study at the end of the course, I expected that preservice teachers' performance would increase more on the posttest. The nature of science concepts often seems abstract, but these preservice elementary teachers had numerous learning supports, such as taking the science course integrated with hands-on experiments and the use of simulation technology. In the end, their views of scientific understanding remained relatively undeveloped. They provided weak responses to most of the essay questions; and carried scientific misconceptions about the concept of physical change of water. Their views did not change much from the pretest.

This situation that preservice teachers go on to teach science with less than adequate proficiency is well established in the literature. Misconceptions are not easily removed from a student's mind, so when preservice teachers hold a misconception that is deeply instilled in their learning foundations, it is difficult for them to accept a new conception (Schoon & Boone, 1998). Eventually they enter into classrooms with firmly held beliefs and conceptions that are resistant to change (Reiner, Slotta, Chi & Resnick, 2000), which they then pass to elementary science students. One could call this an epidemic a self-replicating cycle of misconceptions. It may start with a science teacher and infiltrate into students' brains, continue to be dormant or perhaps mutate through their adulthood, and breakout again as students become teachers to start a new cycle (See Figure 11). It is no wonder the Glenn Commission's report, *Before it's too Late*, described the current situation of science teachers' skills as ineffectual. Pre-service elementary science teachers admit that they face difficulties teaching science due to their impoverished understanding of scientific concepts (Weiss, 1994).

Science Attitude

The overall average mean for the science attitude instrument was 3.13 (SD = .51). As measured in this study, the preservice candidates' attitude toward science was neutral on a 5-point scale.

The following group of items presents a picture on how perservice elementary teachers might be a concern in the science teaching field. A mean of 1.99 (SD = .945) in statement #10 "If given the choice of student teaching, I would prefer teaching science over any other subject in the elementary school" reflects apparent picture on how preservice teachers are willing to avoid teaching science at the elementary level. Statement #9 "Science is my favorite subject", which has a mean of 2.23 (SD = 1.035), is another example of how the subject of science is not favored among preservice elementary teachers in this study. Moreover, the enjoyment level of manipulating science equipments by preservice teachers in statement #6 gives a mean of 2.91 (SD = .947), is another low mean that might reveal something about the students' anxiety on the use of lab tools. Perhaps preservice teachers might be frightened when they are in the presence of tools and technological equipments.

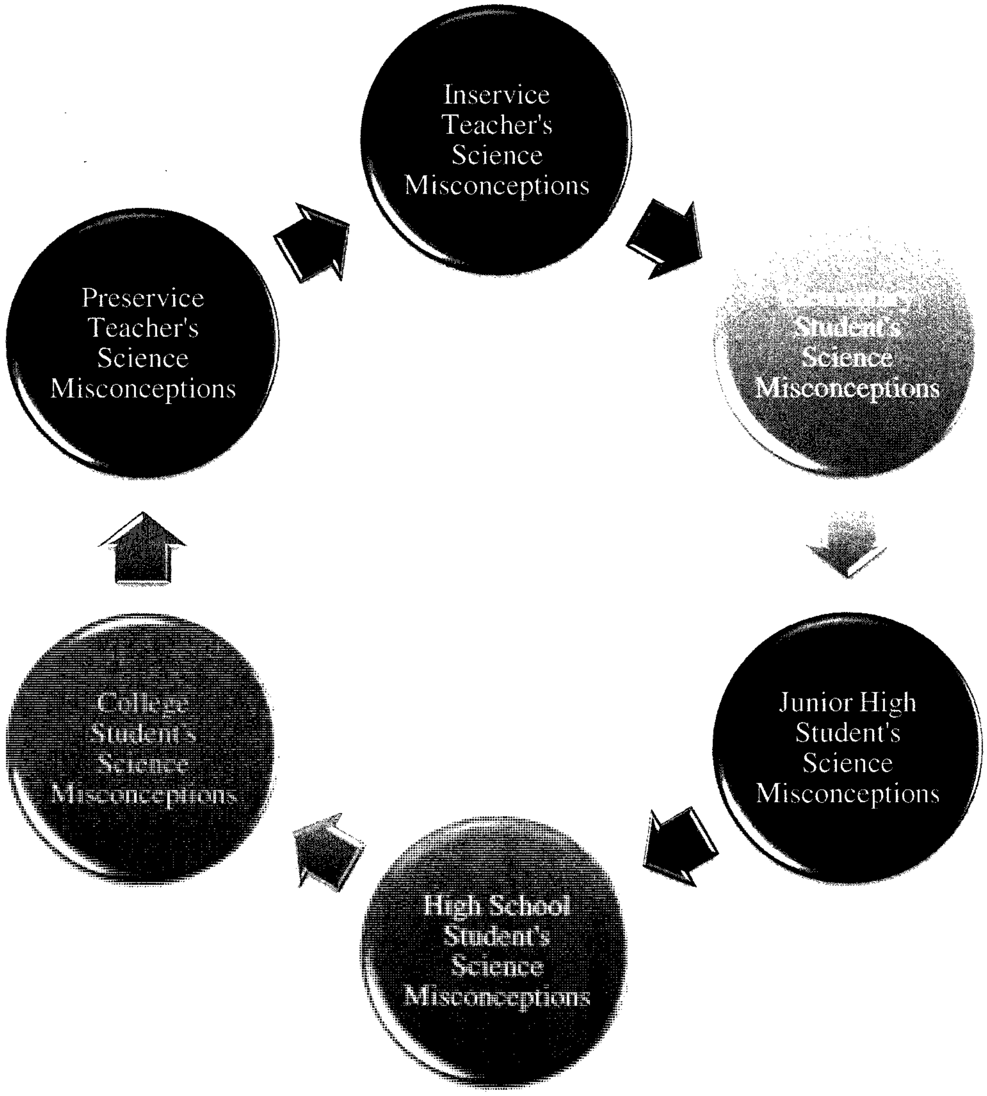


Figure 11. An epidemic, self-replicating cycle of misconceptions.

They might think of them as strange thing that could take more time to be used in science class. Also, they might have the belief that they would face difficulties using such tools compared to their counterpart male students who possibly could do well in the same science classrooms. Statement #2 “I would like to have chosen science as a minor in my elementary education program,” has a mean of only 2.37 (SD = 1.17). It seemed that preservice elementary teacherrs did not like science as minor, but the low attitude in statement 2 could possibly due to that these students have another option different than taking science minor so they would be able to have career more easily. Anecdotal evidence suggested that many students have selected the reading minor since they have addressed that is necessary for employment in some school districts.

When comparing statement #6 “I enjoy manipulating science equipment,” and statement #12 “I would enjoy helping children construct science equipment” the means are relatively low, 2.91 (SD = .947) and 3.30 (SD = .976) respectively. This implies that perservice teachers would not be able to reach out to their elementary students since they lack the enthusiasm to work with the equipments themselves. Simply put, one cannot give what one doesn’t possess.

An interesting point must be addressed that comes from statements #18 “I enjoy discussing science topics with my friends” and #20 “I expect to be able to excite students about science.” While in statement #18, preservice teachers show little enjoyment talking about science in their lives 2.31 (SD = .874), yet they think they will be able to excite their students about science, 3.70 (SD = .697)! Arguably, this attitude composite lacks cohesiveness.

Negative statements #1, #3, #5, #11, and # 19 reveal another phase of preservice teachers' attitude towards science. It is startling to see preservice teachers in this sample having a difficult time accepting science and yet they maybe teaching science. The mean on statement #1 "My mind goes blank and I can't think when doing science" is 3.72 (SD = .982), which reflect the severity and the hardship these students face when thinking about science. In statement #3 "Science is my most dreaded subject" a mean of 3.26 (SD = 1.213) when thinking of science as subject that would scare them off, which coincides with the mean for statement #19 that science is very difficult to understand, 3.25 (SD = .997), or boring, statement #11 "My science classes have been boring," a mean of 3.23 (SD = 1.07). Furthermore, examine the mean of statement # 5 "Science is not an important subject in the elementary curriculum," which is 4.39 (SD = .857). The majority of these future teachers of science seem to believe that science is not an important subject in the elementary curriculum! This is striking, but may not be surprising based on the literature. It seems unlikely to augur well for science education in their future classrooms.

The data collected from this science attitude survey support the notion that preservice elementary teachers have a less than positive attitude toward science. These students are freshmen and sophomores, and it would be interesting to see if their attitudes have changed by the time they take their elementary science methods course. Shrigley (1974) confirms this peculiar notion of many elementary teachers, and it is perhaps seen as cliché in the American education as reported in Chapter 2. This low positive attitude towards science could lead to a reduction of self confidence in teaching science according to Appleton (2007), which may lead to the inability to successfully treat or break the cycle of scientific misconceptions that occur at very young ages of student.

Learning Styles

Like many other students, preservice teachers in this sample encompass different learning techniques, different backgrounds, strengths and weakness, levels of interests and motivations towards learning that perhaps affect on their learning outcomes. Because of these dynamic aspects, pre-service science teachers will likely to learn somewhat differently based on their personal preferences.

As described in Chapter 3, the researcher used a scale from -11 to +11 for each of the four combined dimensions (a) Active/Reflective, (b) Sensing/Intuitive, (c) Visual/Verbal, and (d) Sequential/Global. Scores between 1-3 are considered low, 5-7 moderate, and 9-11 high. Preservice elementary teachers' learning styles could fall on both sides of the four dimensions; Active/Reflective, Sensing/Intuitive, Visual/Verbal, and Sequential/Global, therefore, they can be classified as any of each four dimensions (e.g., visual or verbal learners, active or reflective learners, sensors or intuitors learners, and global or sequential learners). The results of this study showed that perservice elementary tend to prefer active, visual, sensor, and sequential. The majority of the preservice elementary teachers, n = 57 (85%), preferred visual, compared to, n = 9 (13%) verbal. The second highest difference was sensors [n = 54 (81%) compared with n =12 (18%)] for intuitors. For both active and sequential, students had the same relative preference percentages, n =50 (75%), with only n = 16 (24%) reported for both reflective and global.

Though the samples' preferences seemed to have high percentages in one direction of each dimension vs. the other, students had relatively weak preference in all four learning styles dimensions. The different profile between engineering students with strong science background in science and strong learning styles, and preservice elementary teachers' science background with weak learning styles, made it difficult to establish a relationship between the two groups.

Summary and Discussion of All Four Questions

This study investigated four major research questions. The first major question consist of four specific hypothesis that addressed preservice elementary teachers' learning styles (Active/Reflective, Sensing/Intuitive, Visual/Verbal, and Sequential/Global) and their conceptual understanding of the particulate nature of matter in a science class which use hands-on learning integrated with computer based simulated activities. The second major question pertained to the relationship between preservice teachers learning science and their attitude towards science. The third major question related to preservice elementary teachers science achievement gain scores and attitude average affected by their learning styles. Finally, the fourth question pertained to the dissipation or the minimization of preservice elementary teachers' science misconceptions over the course of study. The four research questions will be addressed below in order.

Research Question 1: Does Learning Style Affect Pre-service Elementary Science Teachers' Conceptual Understanding of the Particulate Nature of Matter in a Science Class which uses Hands-on Learning Integrated with Computer Based Simulated Activities?

Summary of Findings for Question 1 by Hypothesis

a. Hypothesis: Active learners will exhibit greater change in conceptual understanding of the particulate nature of matter than reflective learners.

Taken as a whole, preservice elementary students averaged a weak Active learning style. Additional analysis of data, a simple linear regression was calculated predicting subjects' achievement gain based on students' learning style score along the continuum Active/Reflective. As a result, a non-significant regression equation was found ($F (1, 60) = .596$, $p > .05$. suggesting that there was no significant linear relationship between students' learning style (Active/Reflective) and their science achievement gain.

b. Hypothesis: Sensing learners will exhibit greater change in conceptual understanding of the particulate nature of matter than intuitive learners.

In this dimension, preservice elementary students centered around a weak Sensing learning style. A simple linear regression was calculated predicting subjects' achievement gain based on students' learning style score along the continuum Sensing/Intuitive. The regression equation was not significant ($F (1, 60) = .005$, $p > .05$ suggesting that there was no significant linear relationship between students' learning style (Sensing/Intuitive) and their science achievement gain.

c. Hypothesis: Visual learners will exhibit greater change in conceptual understanding of the particulate nature of matter than verbal learners.

In this dimension, preservice elementary students centered around a moderate Visual learning style. A simple linear regression was calculated predicting subjects' achievement gain based on students' learning style score along the continuum Visual/Verbal. The regression equation was not significant (F (1, 60) = .001, p > .05 suggesting that there was no significant linear relationship between students' learning style (Visual/Verbal) and their science achievement gain.

d. Hypothesis: Sequential learners will exhibit greater change in conceptual understanding of the particulate nature of matter than global learners.

In this dimension, preservice elementary students leaned towards a weak Sequential learning style. A simple linear regression was calculated predicting subjects' achievement gain based on students' learning style score along the continuum Sequential/Global. The regression equation was not significant (F (1, 60) = .469, p > .05 suggesting that there was no significant linear relationship between students' learning style Sequential/Global and their science achievement gain.

Discussion for Research Question 1

In their study Zywno and Waalen (2001) tested the influence of learning styles on academic performance outcomes in two different learning environments: hypermedia assisted and conventional. One of their two specific hypotheses was to test differences in achievement between learners in the experimental group. They found there was a statistically significant increase in academic achievement when compared to the conventionally instructed control group. The experimental group had a 0.42 effect size compared with the control group. However, when students' achievement was calculated with respect to their previous academic performance, the effect size for improvement in the experiment groups was higher, 0.65. It seems that the hypermedia instruction was effective for Active and Global learners. Sensing learners improved more than average in both the experimental and the control group. Visual learners also experienced some improvement more than the average class. On the other hand, Verbal learners experienced performance below average in the experimental group, and above average in the control group.

In a similar study, Zywno (2002) confirmed her previous study and showed that hypermedia instruction was effective in improving general achievement, especially of previously under-achieving students. This study did not find large differences in achievement between students with different learning styles, both before and after the instruction. In another study, Zywno (2003) found evidence, with learning outcomes at different levels of Blooms's Taxonomy, that student performance related to knowledge acquisition and routine application stages of learning was significantly better when hypermedia was used. Hypermedia also "offers the lower-achieving students an immediate advantage that allows them to catch up somewhat with their higher-achieving peers." (p. 67)

In our study, it was found that students' learning styles vary on the Felder & Silverman four ILS bipolar scales: Active-Reflective, Sensing-Intuitive, Visual-Verbal, and Sequential-Global. The participant preservice teachers (n=67) on average had a weak Active and Sequential learning style; weak to moderate Sensing learning style, and moderate Visual learning style. As stated in Chapter 2, different students have different learning styles and different approaches to learning (Felder & Brent, 2005). It was expected there would be a wide range of different learning styles on both of the spectrum of each learning style dimension. There is no correct one single learning style, and students have their own preferences accordingly (Felder, 1996). There are also certain features of particular learning styles that coincide with being a good scientists: sensory learners are observant and methodical who can do experiments well, active learners are good in administrations and team work projects, sequential learners are good analysts (Felder, 1993). Considering the preservice students learning styles preferences in this study, it is not encouraging, because their learning styles were leaning towards the weak spot of any of the four continuums in terms of science. There are certain learning styles associated with learning science; but in this study, the students' profile does not match up with these learning styles.

To examine the effect of the independent variable learning styles on the dependent variable achievement, a simple linear regression was calculated predicting subjects' achievement gain based on students' learning style score along the continuums Active/Reflective, Sensing/Intuitive, Visual/Verbal, and Sequential/Global. Because of the attenuated variability of scores on attitude and learning styles, it was difficult to correlate the findings with low gain scores in science achievement. It can be concluded that it was difficult to find relationship between small conceptual understanding increases and weak learning styles. If students' learning styles were found to be strong on each of the spectrum, it would have been easier to compare their learning styles for possible relationship with their science achievement. Zywno (2002) did not find large differences in achievement between students with different learning styles. She explained that by suggesting that the learning style preferences have a weak effect on the learning outcome, perhaps, the sample was small, (n = 119).

So what did simulations and hands on activities do to preservice teachers in this sample of study? In my study, the achievement score did not rise much on the posttest (mean = 3.45 – 2.36 = 1.09). An increase of the mean by 1.09 points seems low for a science class that has utilized numerous of instructional methods and scientific techniques including the use of the hands-on activities and simulation technology. There is a numerous literature cited in Chapter 2 that supports the use of computer technologies in science classrooms. The use of computers promotes understanding of natural phenomena (NRC, 1996). Science and technology are connected and it is perhaps impractical to separate teaching science from the use of technological tools (Norman & Hayden, 2002; Flick & Bell, 2000). Computers can offer active lessons that can convey hands-on learning that capable of match students learning styles (Gardner, 2000). Therefore, inclusion of technology into instruction can foster an increase of student learning, offer new way to think and communicate, and most of all, allow students to learn higher level skills of critical thinking and problem solving (McKenna, Avery &

Schuchardt, 2000). Simulations and visualizations tools support students' critical thinking on scientific phenomenon (Songer, 2007). These are a few examples that are cited in the literature acknowledge the use of technology in the science classroom. In my observations of the course, there was no evidence that corroborate preservice elementary teachers shy away from the uses of computer simulations.

Perhaps one explanation to the low science achievement on the posttest was that not every activity proposed in the classroom allowed preservice teachers the use of computer simulations, and instead they used the hands-on tools only. According to Zacharia and Anderson (2003), the use of simulations prior to inquiry-based laboratory experiments resulted in the improvement of students' ability to make acceptable predictions and explanations of the phenomena. Assuming this what happened in the science content class, then, it would support the argument that the students' low prediction and reasoning with science concepts is largely related to the separation between the use of simulations and the hands-on activities in a lab setting. Consequently, it could possibly be the key to the low achievement score. The study of Jimoyiannis and Komis (2001) on velocity and acceleration using traditional methods of teaching and simulations concluded that computer simulations reinforces students' conceptual change in a gradual process at the same time simulations can complement other instructions, such as hands-on tools to create faster and deep learning and to further facilitate students' understanding of the two physics concepts. Therefore, a unilateral way of using a single method of teaching science could result in deficiencies. Simulations have helped learners in the science classroom, yet when mixed with the hands-on laboratory experiments, students could get higher achievement (Deniz & Cakir, 2006). It is possible that the use of simulations was not coupled simultaneously with hands-on on all of the activities required in the science content course. If the science content class used a combination of hands-on activities which preceded computer simulation, science achievement results may have improved more.

Conclusion for Question 1

Although perservice teachers in this sample had a wide range of learning styles, these learning styles fell in the range of weak to moderate on each of the four dimensions of the ILS. It was found that individual learning styles did not have any significant relationship to the preservice teachers' conceptual understanding of the nature of matter in a simulation-based learning environment. The limited of variability in both measures made finding relationship unlikely.

Although this study did not find a large change in preservice teachers' conceptions and achievement with the use of simulation technology and hands-on activities, there is a plethora of empirical research presented in Chapter 2 which suggest the use of simulation can be helpful in dealing with abstract science concepts such as the nature of matter, and the importance of use the hands-on tools coupled with the use of technology.

Research Question 2: Is Pre-service Elementary Majors' Science Learning in a Course using Hands-on Learning Integrated with Computer-Based Simulations Related to their Attitude Towards Science?

Summary of Findings for Research Question 2

A simple linear regression was calculated predicting subjects' achievement gain based on students' attitude. The regression equation was not significant (F (1, 62) = .612, p > .05), suggesting that there was no significant linear relationship between students' attitude towards science and their science achievement gain. An examination of the scatter plot provided evidence that there was no nonlinear relationship either.

Discussion for Question 2

The researcher found no significant linear relationship between students' attitude towards science and their science achievement gain in this study. Preservice teachers did not score particularly well on the posttest. It is possible that their views towards science before taking science content course were not positive. My speculation is if elementary teachers had strong positive attitude about science subject, they would have probably chosen a different major that involved more direct work with science. Instead, they chose to be "generalist" elementary teachers. It could well be that preservice teachers in this sample carry negative attitude towards learning science developed long before they attended college classes. As a result, this negative feeling about science may have contributed to their low achievement score. As mentioned in Chapter 2, attitude is a mental concept, which is reciprocated with feelings, that a person can desire or refuse a certain object (Koballa 1988; Shrigley, Koballa, & Simpson, 1988; Simpson, Koballa, Oliver, & Crawley, 1994).

Preservice elementary teachers have taken science courses in high school before they took the science content course at the college level as a requirement for their elementary teaching certificate. Some were exposed to different types of science courses in elementary through high school. Also they have been exposed to different kinds of teachers, generalists as well as teachers with more science and chemistry background and orientation. The preservice elementary teacher subjects of this study started out the course with a low attitude towards science as the results indicated in Chapter 4.

As stated in Chapter 2, a decline of young people enrolling in science classes, and pursing scientific careers, as well as their lack enjoyment in science classes, pushed science researchers to study science attitudes (Osborn, Simon, & Collins, 2003). Shrigley (1974) reported that "many elementary teachers have less than a positive attitude toward science is one of the truisms of American education" (p. 243). Harlen (1997) found that elementary teachers in England listed science 8th out of 11 different subjects according to their confidence in teaching all the subjects. Implied from researches, it seemed that students are shying away from the learning of science. This leads to develop undesirable attitude to the subject of science especially at the pre-college level. It is rather crucial to place emphasis on the change of preservice teachers' perceptions towards not only understand science, but also to motivate them to teach science well.

The preservice elementary teachers in this sample were exposed to an inquiry-based science course that utilized computer technologies. Early in the course, the students scored a low attitude towards science. There might be a negative impact on their science achievement scores due to their low attitude towards science. As cited in Chapter 2, exposure to inquiry-based courses has the tendency to promote short-term change regarding student attitude that involve social change (Fletcher, 2000), and students held positive attitude towards science inquiry as a process in science when exposed to a learning cycle-based course (Fletcher, 1996). It is therefore, plausible to note that since preservice elementary teachers took the content course with all the technology involved, their attitude towards science would increase. Thus, it was expected they would have higher outcomes on the post achievement test than on the pretest assuming attitude has a short-term impact on achievement. It also important to acknowledge that the time for this study was relatively short to change students' attitude towards positive about science. My data does not reveal evidence on this; however, given a plethora of literature talking about unqualified science teachers, it would not be reasonable to assume that these preservice teachers probably had some teachers prior to college who taught science poorly in addition to using traditional methods of instruction; hence, their science knowledge was limited. Perhaps, the inadequate teaching of science courses resulted in a change of heart about science. It is important to note that the lack of familiarity of the curriculum by the IiPS faculty may had an impact on students' performance. The faculty members of the course during that semester were relatively new to the course. All of above reasons may have contributed to the low attitude score and then to the low science achievement. The students may have felt overwhelmed and challenged, and therefore, their performance did not increase as much as was expected on the science test.

Conclusion for Question 2

There was no significant linear relationship between preservice elementary teachers' attitude towards science and their science achievement gain. Preservice elementary teachers did not accomplish acceptable high results on the posttest. This could very well mean that their attitude towards science was low and lingered unchanged when they started taking science content course. This could well be that preservice teachers in this sample carry negative attitude towards learning science prior to taking a science content course at a college. The negative feeling has reflected on their low achievement score. As stated in the literature, attitude is a mental concept, which is shared with feelings, that a person can desire or refuse a certain object (Koballa 1988; Shrigley, Koballa, & Simpson, 1988; Simpson, Koballa, Oliver, & Crawley, 1994). Therefore, preservice elementary teachers have the desire to teach science subject to elementary children, but their feelings towards learning science is not strong. Because it is compulsory to teach science to elementary students, this becomes a challenge for them. Hence, such teachers may, perhaps, use methods to avoid such challenge, such as teaching little physical science where they have less confidence, and dodge difficult questions (Harlen, 1997), or answering students' questions with the wrong information that lead to science misconception. This would not be helpful to their future students.

Research Question 3: Is Pre-service Elementary Teachers' Achievement Gain Scores Affected by Attitude and Learning Styles?

Summary of Findings for Question 3

In examining the third question, a multiple linear regression was used to predict subjects' achievement gain scores based on students' attitude toward science and their scores on each of the 4 dimensions of learning styles Sequential/Global, Active/Reflective, Visual/Verbal, and Sensing/Intuitive was not significant (F (5, 55) = .362, $p > .05$. Attitude and the four learning styles dimensions together cannot be used to predict students' achievement gain.

The findings from the first question and the second question were of no significant relationship. As stated in question one, there was no significant relationship found between achievement test score and preservice teachers' learning styles. Also, findings from question two institute no significance between achievement gain score and preservice teachers' attitude towards science. In retrospect, no correlation between attitude and preservice teachers' learning styles was found. Therefore, this supports the fact that the correlation between attitude and the four learning styles dimensions together cannot be used to predict students' achievement gain.

Discussion for Question 3

As explained in Question 1, the limited variability in learning styles made it hard to establish connections with their relatively low achievement gain scores. It would have been possible to relate the students' learning styles to their science achievement if their learning styles fell more distinctively in higher ranges on each of the 4 dimensions of learning styles. Participants in this study were not selected individually according to who was active and who was reflective; instead the class as a whole was chosen. Therefore, there was no probability of speculating on those who would perform well on the science achievement test and those who would not. There is still a possibility that a study with more separated learning styles would have found a significant relationship with students' science achievement.

Is preservice teachers' science achievement affected by attitude? There are many possibilities one would consider about students' attitude towards science including their past experience. Different kinds of science materials ranging from low/high science content to "cook books," and different teachers who are considered unqualified in their teaching to science may have impacted their attitude towards science. The notion that attitudes towards science is been carried over to the next level of schooling is addressed in the literature. Gibson and Chase (2002) suggested that when children develop attitudes towards science at an early age of education, it is hard to change when children reach middle school. Possibly preserive elementary teachers carried over their negative attitude towards science to the college level. If so, the students may not have emphasized their learning of science due to the poor attitude to the subject of science. It is almost impossible to change students' attitude towards science by taking eight weeks of science content course over the period of one semester.

Conclusion for Question 3

The results indicate that there was only a weak positive correlation between preservice teachers' attitude and their learning styles on achieving a higher test score.

Less variable or distinct learning style distributions on the 4 dimensions combined with the relatively low preservice teachers' attitude towards science may have made it hard to establish relationship with the scores and relatively less variable on the science achievement test. However, there are certain circumstances that might have made learning styles of preservice elementary teachers to be in the weak range of the 4 dimensions, such as using the whole class to represent the sample of the study rather than selecting students who have strong learning styles on one or the other dimension. In addition, there could be other circumstances that led to lower students' attitude score previous to college science content course.

Research Question 4: Were Preservice Elementary Teachers' Science Misconceptions Dissipated Over the Course of the Study?

Summary of Findings for Question 4

The simple answer for question 4 is no. Misconceptions do still exist in the preservice elementary teachers' answers. These inappropriate conceptions are hard to dissipate over the course of one semester, especially if their roots were in the early stages of the child's education. Evidence is that the preservice elementary teachers' comprehension of science concepts is limited. Science misconceptions are deeply rooted and preservice teachers could not rectify their existing science knowledge in the time given. The subjects particularly had trouble with the distinction between chemical and physical changes. The notion of water evaporation seems to also be a nebulous concept to many of the subjects.

The Ph.D. students, on the other hand, had fewer misconceptions. The common misconception among preservice teachers of water being broken down to Hydrogen and Oxygen after boiling or evaporating did not exist among the doctoral students. However, some misconceptions that existed among preservice elementary teachers also existed among graduate student in chemistry. This could mean the misconceptions are so deep that not only could it take more than one course to address, but might need to be specifically addressed in manner not typically presented in chemistry problems. The literature asserted that science and chemistry misconceptions are found across wide range of the spectrum, and does not relate to a certain age. The results of this study support the finding.

Discussion for Question 4

To test the fourth question, the researcher analyzed preservice teachers' answers on the essay questions. It was found that some preservice teachers' answers on the fourth pre essay question did not match that of a consensus scientific answer. The question asked if liquid water molecules at 24°C move slower than gaseous water molecules at 100°C. Some participants, such as SAJ6, showed scientific misconception on the pretest essay answer (e.g., "B/C liquid molecules move faster than gas molecules"). It appears that the same participant had a better answer to the same question on the posttest, thus, providing an evidence of improvement during the course. Though the answer was enhanced over the pretest, yet it did not ascend to a full comprehension level.

In question five, "when water is vaporized, it is changed to," some of preservice teachers' answers in the posttest were as follows:

Particles cannot split apart.
Hydrogen + Oxygen by themselves would not make water.
The molecules are just being vaporized they are being broken apart.
Goes into the air as hyd. & oxy.
When water is vaporized it is changed into hydrogen & oxygen. It is no longer a liquid solid or gas. It turns into water vapor.
It breaks up when it changes state which makes it separate out from being H_2O it goes to H_2 & O.
It separates out.
The particles break up & turn into separate things.
The 2 particles do not fully separate.
If it were evaporated to H_2O and not to Oxygen the vapor would be very flammable.
"H_2O →breaks down into its separate molecules 2 hydrogen and 1 oxygen."

Prservice elementary teachers may have entered the education field to teach elementary students with less enthusiasm about teaching science subjects. The overall results on the posttest essay for all classes suggests some concern for preservice elementary teachers in teaching science. Roughly fifty-four percent of the subjects answered wrong on both pretest and posttest. Thirty-six percent changed their preliminary wrong answer on the pretest to the right answer C on the posttest. Three percent went from right answer C on the pretest to any wrong answer on the posttest. Finally, only 3% of the preservice elementary teachers have answered correctly on both pretest and posttest multiple choice questions. Explanations showed numerous misconceptions.

These misconceptions must have come from somewhere. As was indicated in the literature, Fulp (2002) found 3 or less out of 10 elementary science teachers have deep science content knowledge and are considered well prepared to teach science. In addition, preservice elementary teachers had limited explanations, and minimum use of scientific concepts in their essay answers. A prediction can be made pertinent to the wording and clarity of the question being asked in the science achievement test "Please elaborate and justify your reasoning. Identify any assumptions you are making." During the class observation, the researcher clearly explained what essentially needed to be done to answer the questions. Furthermore, he told the students to ask any question for further clarification, but none did. The researcher assumed that questions were understood by all students. Possibly, preservice elementary teachers were not familiar with these types of questions, or most likely they have nuance or no experience in providing explanations that focus on Sates of Matter and physical/ changes. They also had a sufficient amount of time to answer all six questions.

As far as graduate student answers to the achievement test, all five doctoral students gave the right answer for question #5 (water evaporation) with no science misconception in their answers. In question #2, however, it was revealed that one of the students suggest an answer that reflected limited comprehension to the question. His answer was vague, and possibly can be considered as a scientific misconception:

> There would virtually be no change since CO_2 is still a gas and will be evenly dispersed in the beaker until a phase change.

The particulate nature of matter is essential in the science field, but it is also a difficult concept and even graduate Ph.D. students can fall science misconceptions. Bodner (1991) found that 25% of his graduate students had misconceptions related to the boiling of water concept.

A full comprehension answer by preservice elementary teachers to the concept of water being vaporized was not shown in their answers. Many based their answers on the fact that water dissociate into its diatomic molecules O_2 and H_2, a chemical phenomena that could occur not by boiling water, but only under certain conditions that provides enough energy such as in "electrolysis". As stated in Chapter 2, the study of Osborn and Cosgrove (1983) of forty-three school students, ages 8-17, indicates an excellent example of how students from different ages fall into different views about the water concept of evaporation. They found that students' understandings of scientific concepts are shallow; they tend to use their scientific knowledge to support nonscientific beliefs; and most of all, they found that 15-year-old students fell into misconceptions more than the younger, 12-years-old students as to how water changed into oxygen and hydrogen on boiling. In general, the majority of the student sample believed that the bubbles in boiling water are made up of heat, air, or oxygen and hydrogen. It seemed that students' wrong ideas were influenced in unexpected ways by science teaching. These results are consistent with our study in that many preservice elementary teachers misconceptions resembled those of other students from 8 to 17 of age. They showed that they still held wrong views about science and that oxygen and hydrogen separates in the process of boiling water. This may give a clearer picture on how misconceptions can be resistant and can be carried over by students to the next level of education. Preservice teachers in this study have common misconceptions regarding the physical change concept. Overall, preservice teachers' science misconceptions did not dissipate by the time they finished the science content course.

Conclusion for Question 4

This study provides evidence that the preservice elementary teachers' comprehension of pertinent science concepts is limited. Their science misconceptions continue to be alive even after they have finished the science content course that is designed to include inquiry in addition to computer simulations to help elementary students overcome their science deficiencies. They tend to have confusion between chemical and physical change, a concept might perhaps be considered a fundamental issue in science learning. Since they are freshmen and sophomores it is, therefore, recommended that preservice elementary teachers need to continue to take physical science content courses and their elementary science methods course to address and inhibit these misconceptions.

The small sample of graduate students, on the other hand, had fewer misconceptions, but several persisted. The common misconception about water breaking down into Hydrogen and Oxygen after boiling among preservice elementary teachers had no place among doctoral students, nonetheless, some students brought up a non scientific ideas (e.g., student #5, in question 2, they chose A for the multiple choice question and explained that "There would virtually be no change since CO_2 is still a gas and will be evenly dispersed in the beaker until a phase change."). Bodner (1991) found that 20% of his 132 graduate students in chemistry believed that the bubbles that are made when water boils up consist of air or oxygen, and 5% believed the bubbles are a mix of Hydrogen and Oxygen. This suggests that misconceptions exist not only among elementary education majors, but even among some graduate students who are majoring in science or chemistry.

Implications for Science Teaching

In this section, implications for science teaching will be drawn from the study's findings. This study focused on perservice elementary teachers enrolled in a physical science content course taught by two different instructors at the University of Northern Iowa. These future elementary teachers exhibited limited comprehension of the particulate nature of matter, and showed flaws, or misconceptions, in their understanding of physical change and gas concepts. In reading these implications, please remember that this study cannot generalize to all preservice teachers or to all areas of science. These implications for science teaching are corroborated by the literature; however, in several ways I have extended the literature through this study. A discussion of six implications for science teaching practice follows.

Implication 1: The preservice elementary teachers have not had enough science, and have incomplete or inaccurate science concepts of the particulate theory.

One evidence for this conclusion is how low the preservice elementary teachers' pretest scores, and even posttest scores, were very low. Although this study did not specifically investigate their background, anecdotal evidence suggests that almost 50% of the subjects in the study may not have had chemistry or physics in high school at all. Iowa does require several science credits to graduate, but not necessarily chemistry and physics as such. In addition, many of the subjects took science courses in elapsed time. As a result, the elapsed time may had a negative effect on the elementary science's knowledge retrieval. According to the Glenn Commission's report *Before it's too Late*

(2000), science teachers should only be considered competent if they have at least a minor in their main teaching field. This is troubling if this means these future teachers will avoid science or influence their elementary students with science language that is not acceptable to the science community. The scenario of science teachers with limited science content knowledge has been continuous for decades as portrayed in the literature. Appleton (2007) noted that the tendency of elementary teachers to avoid science has not changed in twenty years. In general science teachers have limited science subject matter knowledge, limited science pedagogical content knowledge, and low confidence (Appleton, 2007, p. 497).

It is not enough to have new in-service teachers teach science the way they were taught as K-12 students. The preservice teachers in this study were freshmen and sophomores. Some of them will choose to have a minor in science teaching. However, most will not –and for these students the science content class studied in this research would be the last science content class they have. The evidence, then, in his case, that they require more preparation to tackle meaningful science teaching. This could mean that a future science method course that addresses student misconceptions is needed to help prepare preservice elementary teachers. Acquiring preparation and science knowledge is supported by the 2000 National Survey of Science and Mathematics Education, which acknowledges the lack of elementary science teachers' content knowledge (Fulp, 2002). As was shown in Chapter 2, the science field has acknowledged the insufficiency of conceptual understanding of preservice science teachers, which, in turn make them unprepared to teach science (Weiss, 1994).

Implication 2: Science curriculum needs to emphasize advanced reflective reasoning using new instructional strategies that address atomic and molecular theory.

Many explanations for their answers given by the preservice elementary teachers were weak. They had limited understanding of the microscopic and macroscopic properties of matter and phase changes. Many of the preservice elementary subjects seem to have ill-conceived scientific conceptions. According to the evidence presented in this study, part of a single one-semester science content course was insufficient to change long-term misconceptions held by students.

The limited science knowledge of the preservice elementary teachers in the study was further shown in their answers to the question about to the vaporization of water when they were unsuccessful in distinguishing between chemical and physical change in water when heated. The majority of the subjects said that hydrogen and oxygen are the consequence of water evaporation, which is similar to a common misconception about water vapor found in the literature (Bodner, 1991). Even worse, some preservice elementary teachers said that water vapor is "flammable." It should be known that the two components or elements that make up water--oxygen and hydrogen—are reactive/oxidizer and highly flammable gases respectively, but when combined to form water compound, they are used to fight fires. It seemed that future science teachers did not apply on the achievement test what they learned in the science content course. In a broader sense, the preservice elementary teachers studied still hold low reasoning ability for in explaining scientific phenomenon. Therefore, new effective instructional strategies that address more reasoning are required.

Implication 3: To fix student's conceptual ability to explain scientific views, curriculum needs to specifically focus on the use of scientific terminologies.

It is apparent in the subjects' pretest essay answers that these preservice elementary teachers did not use many of the science terms that are vital in explaining science phenomenon. Even by the posttest, the subjects generally did not incorporate the science or chemical terminologies that they learned in the science content class. These terminologies include particle collisions, chemical or physical change, pressure as related to fewer molecules in the same amount of space, the proportionality of atoms in molecules, kinetic energy and its association with the motion of an object.

It should be noted that the fact that the instructors of the science content course would not give extra credit as a motivation component was probably a factor in the reduction of their explanations to the essay questions. The subjects may not have wanted to expand extra effort working on a science test that would not be included in their final exam. It is possible, therefore, that they gave answers as brief as possible and did not extend themselves to think more deeply or search for the scientific terms needed for their explanations.

Overall, the preservice elementary teachers still showed low conceptual ability to use influential science terms. This suggests that the students need additional science courses and their elementary science method course to help address these conceptual abilities.

Implication 4: To fix student's conceptual problems, curriculum needs to specifically focus on misconceptions.

The preservice elementary subjects of the study showed a variety of misconceptions on both pretest and posttest. There were patterns of persisted, profound, and common misconceptions found among preservice elementary teachers concerning the particulate and the kinetic nature of matter. My recommendation is that a science content course could more contribute to preservice students' conceptual change if curriculum designers incorporate a segment that specifically addresses misconceptions, especially those misconceptions that have persisted for decades. It is important to have a concept-based curriculum that mainly emphasizes students' conceptual thinking to address the reasons contributing to students' resistance to correct scientific conceptions. Although the focus of the course was on Interaction and Energy --which are broad themes-- does not mean that curriculum designers exclude the physical and chemical changes themes. Chemistry and the particulate nature of matter are as essential as any other science topics that cannot be marginalized. To successfully reverse such ill-conceptions, I would recommend testing preservice elementary teachers for research in a large study by designing chemistry activities that involve a combination of methods, which can be more effective to make preservice elementary teachers acquire multiple sources of investigations to any scientific activity. The methods are: (a) hands-on techniques to show, for instance, the structure of molecules and their atomic components, (b) computer simulations techniques that provides three-dimensional images of molecules. This may help preservice elementary teachers visualize how molecules are connected by bonds/forces that keep them together in a natural state. The combinations of methods can create an atmosphere that would allow science teachers in the classroom to locate misconceptions in the students' thinking, incorporate them into the class, and guide students to discuss such challenging scientific concepts. Also these classroom activities may help preservice elementary teachers to test their previous thinking and reevaluate their comprehension to abstract science concepts that enable them to formulate better reasoning ability upon explaining scientific ideas (Zacharia & Anderson, 2003; Songer, 2007).

Implication 5: To build a correct scientific conceptual framework, curriculum needs to have a segment at the beginning of each unit that focus on persisted preconceptions that students bring to college science classes.

Many preconceptions and misconceptions were found on the pretest essay answers. The purpose of this study was not to determine whether the science content course addressed science misconceptions. Based on our data, the science content course did not; but, then, the course did not focus on identifying ameliorating misconceptions in the two units--Interactions and Behavior of Gases, and Interactions and Physical Changes--and applying them in everyday life. Perhaps the way the science content course was taught did not strongly address different learning methods that would contribute to the elementary preservice students' conceptual understanding. Furthermore, the future elementary teachers may not have quality science at any level from the elementary to high school.

Implication 6: To make preservice teachers conduct logical connections regarding specific science concepts, curriculum concept-based must address logical interpretation.

The preservice elementary teachers in this study used a variety of faulty rationales in their explanations of science phenomenon. For example, a number of subjects thought that when water evaporates, it releases hydrogen and oxygen. They may see a logical connection in their minds between water and its components being separated. However, in this case, they are missing part of the premises, which is part of logical reasoning in science. The teacher can understand where such logical lapses in reasoning come from, and then they can help test it, and reconstruct a more acceptable reasoning. Thus, if the curriculum focused on fact that water requires energy to break bonds within the molecules to release hydrogen and oxygen, and that this level of energy cannot be made available by heating water, they would have a check on their misconceptions. Students can think creatively, but they need correct information to work from. To do this well, teachers have to be even more creative thinkers to guide students along a misconception free pathway.

When preservice teachers become inservice teachers, they tend to teach elementary students content knowledge the way they were taught (Lederman, Newsome,

& Latz, 1994). They will do so regardless of the misconceptions these ideas contain, simply because they are very familiar with them. The consequences are that their students will absorb the same misconceptions, and this will tend to continue in an indefinite cycle of erroneous teaching.

A Robust Cognitive Model for Science Education

As explored in the literature, the particulate model of matter is not only a vital idea in modern science, but is also a topic that is very hard for students to learn and conceptualized due to its abstract nature (Snir, Smith, and Raz, 2002). Evidence in the science education field suggests that preservice elementary science teachers lack an accurate understanding of science, and that they often interpret science phenomena nonscientifically (Weiss, 1994; Haidar, 1997). A potential educational disaster is possible when perservice teachers enter the teaching field and encounter elementary students with naïve science concepts. Elementary teachers may mislead students if the teachers' understanding is flawed or unqualified. Loughran, (2007) notes that unqualified teachers don't have enough background to give students what they need to construct accurate and useful knowledge, especially when teachers pass on flawed science conceptions.

For decades, many researchers have talked about misconceptions, naive concepts, and alternative misconceptions as developed in Chapter 2. Though teaching science has shifted from a traditional approach to one that is more inquiry-based, learner-centered, and technology rich, the solution to the problem of misconceptions still eludes the field. As of today, science students at all levels, experience relatively similar patterns of misconceptions as those from decades ago. Because misconceptions are deeply embedded in the preservice elementary teachers, they are a cause of enormous concern to the field of science education. To change this system, work must be done to reevaluate science curriculum and pedagogy from the bottom up, with an emphasis on creating powerful ways of using technology to address the problem, creating a new atmosphere for preservice elementary teachers, and taking drastic measures to put an end to the cycle of chronic science misconceptions.

Preservice teachers have experienced science curriculum from elementary through high school. Therefore, basic foundational content for the preservice elementary teachers' knowledge of science should have been established prior to taking the science content courses at the college level. Yet, the subjects in this study still brought naïve conceptions to the classroom (e.g., the process of water evaporation water separates the two elements, hydrogen and oxygen). It is, therefore, crucial to create a rigorous learning model at the college level that would incorporate all the elements that preservice teachers need before they are hired to teach elementary science.

Preservice elementary teachers need not only to pass science courses that are required to teach elementary school, but need more to compete nationally and globally. The literature suggests a need to keep up with the worlds' pace and to satisfy the US demands (e.g., NSES, 1996; National Research Council; NRC, 2007). Based on my literature and empirical research, I would like to propound a rigorous science education model to be taken seriously before giving the preservice teacher the title of elementary science teacher. A discussion of the three dimensions of my model follows.

Dimension 1: Preservice science teachers must have sufficient content knowledge as the cornerstone to teaching science.

Dimension 2: Preservice science teachers should have the capacity and the creativity to recalibrate what they have learned in school and what they have experienced from other extracurricular activities from real life world to make learning science dynamic and not static.

In some cases students are able to pass science without achieving deep understanding. For example, Larson (1995) observed what he called "Fatima's Rules." The bright high school student named Fatima was able to get the right answers without in-depth understanding of the subject matter. The rules that Fatima used for succeeding in science were: (a) Don't read the book; (b) Don't pay attention to any information not reviewed in questions at the end of the sections and/or chapter; (c) Look for charts, tables, and bold words; (d) Ask the teacher for help as soon as you're stuck; and (e) Don't split up the work among members of the group to save time in getting answers if questions move sequentially through the chapter (p. 8).

Part of the sample in this study was taught by an adjunct with a Master degree in science education and a high school teaching background. The smallest class was taught by a Ph.D. tenure-track, assistant chemistry professor. Both instructors are relatively new to teaching at the college level and with the PSET curriculum. Given this information about both instructors in addition to the weak achievement shown by the sample on the science achievement test, it is perhaps reasonable to believe that perservice elementary teachers had difficulties passing their science content course. However, if their final results in the science content course indicate that they have done well on the final test, especially on gases and physical change, then the assumption is that (a) the science achievement test was hard on students due to the way it was designed, (b) students are familiar already with the types of questions they encounter in every test in the science content class, and/or (c) isn't reasonable to consider the possibility of a similar use of "Fatima's rules" to pass the science test? The class setting is perhaps conducive to such rules; where small groups of students setting adjacent to one another on one table, work together on same class assignment cooperatively, and each group would like to finish the class assignment in the same time. This may be a fertile environment to apply "Fatima's Rules."

Preservice elementary teachers ought to think critically and construct new ideas to improve their science teaching experience, enable them to minimize naïve science ideas, and be more qualified for teaching science. They must think, imagine, discuss critique, reflect, analyze, evaluate, and persevere in science. Piaget (1964) asserted that the "goal of education should be to form minds which can be critical, can verify, and not accept everything offered."

Dimension 3: Preservice elementary teachers should have a positive attitude towards science.

As a precondition to be excited about teaching science, preservice elementary teachers should have a positive attitude toward science. Researchers in this area assert that it is possible to turn a negative attitude toward science or science education to a positive one. If they do not have one when they come in, they should either be counseled out, or the curriculum needs to focus on helping them develop a better attitude in to a positive one. According to Shrigley (1974), if attitudes are not born but learned, then this means that positive attitude toward science can be taught. Changing preservice elementary science teachers' attitude to be positive toward science is, perhaps, a daunting task especially at the college level. It may be doable if certain elements are considered:

1. Preservice elementary teachers could be interviewed when applying to be in the elementary education program. This interview may give the interviewer an idea of the students' background and attitude toward science, and if they are motivated to teach science to elementary students. The interview can be made face-to face or by using a science attitude survey. Quality prospective perservice students may, then, be chosen to sign up for the elementary education program.

2. If prospective elementary teachers fell somewhat low in their science attitude, but still chose the major, then a well trained or specialized science educator needs to be teaching the science content course. The specialized instructor science teacher can: (a) create a class environment that allows students to have more confidence of themselves in dealing with science, (b) emphasize the idea that science is an important subject to elementary students. It should be taken seriously because it can be considered the basic foundations and the first glimpse of light for children at a young age, (c) create an atmosphere that allows preservice elementary teachers to feel less pressure when they come to class by doing group activities that would allow them to feel they are in a real elementary school setting with children and enjoying every minute of the class learning science, (d) when asked a question in the classroom, search for a scientific answer to

guide students to the right science path rather than giving them an obscure answer that may mislead their thinking, and (e) knowledgeable in the innovative curriculum being used. This way, the preservice elementary teachers would build more confidence and reduce the anxiety that may have helped them create a negative attitude toward science. In this study, the PSET curriculum was being implemented for the first time by instructors of the course.

3. Designing a simulation program that is meant to support and ease the use of hands-on activities. As stated in the Chapter 2, simulations and hands-on tools go hand-in-hand to enable preservice elementary science teachers not only to have effective science learning from simulations, but also to enjoy the excitement of using materials and tools that represent the daily work of elementary students. The simulation program should be designed to also enable preservice elementary teachers to cope with misconceptions. The simulation program should include activities that are abstract and difficult to conceptualize. For instance, the simulation should include an activity about water evaporation that shows the entire process in three dimensions similar to real life experimentation. It should show what happens after water is heated in a beaker and reaches 100° C, and water vapor starts to rise. Students, then, show that they can collect water vapor, and test it with certain simulated tools provided within the program. Students, then, can make their own conclusions to see whether the vapor is "flammable," explosive, or if there are any combustible gases being released in the air.

The same heated water experiment can be repeated using real materials in the lab; perhaps comparing it with producing hydrogen and oxygen using a Hoffman

Voltammeter. Preservice elementary teachers would follow certain guideline to avoid any hazardous things that can occur by doing the hands-on experimentation. The computer simulation program should include multiple activities that address concepts when the preservice elementary teachers have encountered misconceptions. The computer simulation program could help students to (a) tackle issues of misconceptions heads on, and give students evidence beyond doubt regarding abstract science concepts; (b) connect with materials they will use with elementary students in their career; and, (c) make science activities less boring and keep students more attracted to the activity with their peers, hence, changing their neutral or negative attitude about science to positive. Hopefully, then, preservice elementary teachers may pass on the positive attitude they acquired to new school generations, creating an upward, positive spiral. Figure 12 below shows a robust cognitive model for science education.

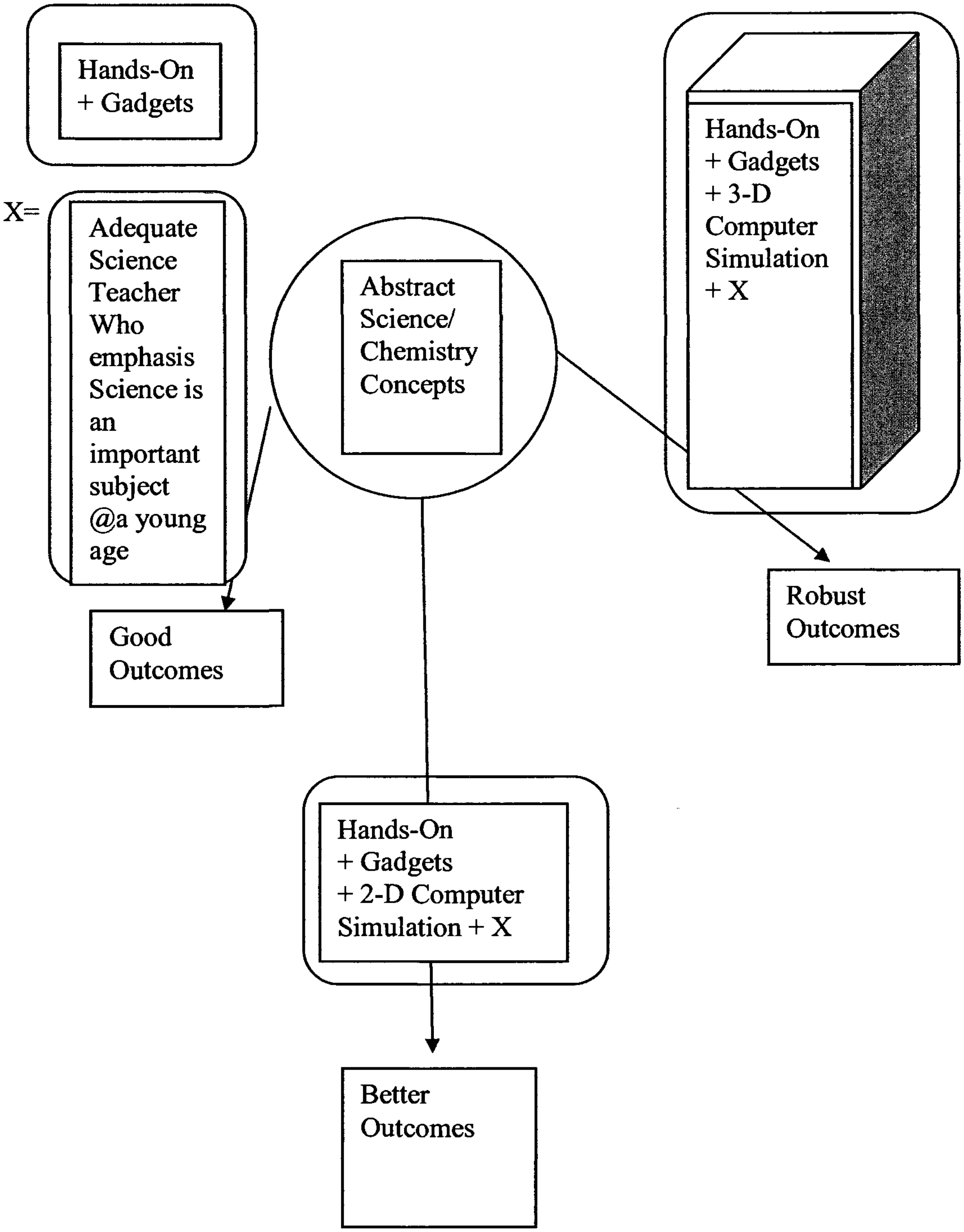


Figure 12. Model for cognitively robust science education

Suggestions for Further Research

- Redo the study with a sample that includes students with stronger scores on each of the four learning styles dimensions, making it easier to see potential relationships between them and science achievement or attitude.
- Further research that address comparing adequate and dynamic science teachers from magnet schools with other science teachers relatively low in science.
- Further research that compare preservice elementary teachers and with those whose majors specifically directed towards the study of science and engineering.
- In my study, students were from everywhere who were not focused on teaching science per se. Therefore, it is important to have studies with a sample recruited from science magnet schools or private science focused-schools. These types of schools focus exclusively on academic subjects such as science. Although magnet schools are funded by the state, they only attract very talented students who are able to take college level science courses and accept high challenges. In addition, these types of schools can hire teachers who are experts in science or math.
- Research that test three-dimensional simulation programs that address abstract science concepts including misconceptions.
- In my study, the preservice elementary teachers' attitude towards science was roughly neutral. Therefore, more studies are needed to examine ways to improve students' attitude in science learning towards the positive.
- In my study, preservice elementary teachers had a variety of misconceptions related to the behavior of gases and physical/chemical changes. Further study, a

sample of preservice elementary students with background in chemistry in comparison with another sample with background in general science.

- Further study is needed to correlate students' performance on PSET curriculum with performance on science achievement instrument to test students' comprehension on both instruments and to test the instruments' reliabilities.
- Out of 68 students in the study, maybe 10 will minor in general science teaching. Further study to compare students' attitude at the beginning of the science content course and at the end of their science method course, testing their conceptual understanding at the same time.

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APPENDIX A

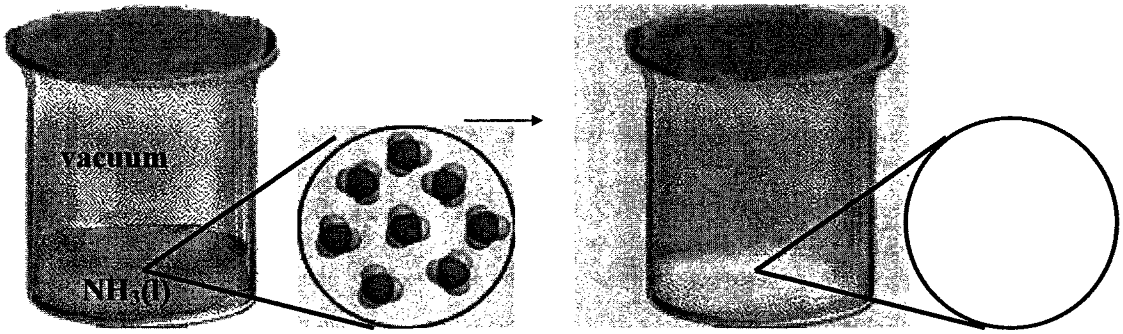
SCIENCE ACHIEVEMENT TEST

Student ID Code:______________ Date:___________

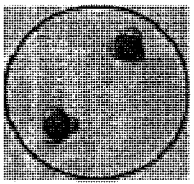
Please answer the following questions to the best of your knowledge. After you select your answer, explain your reasons for chosen that specific answer.

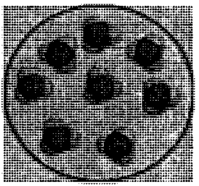
Remember these conceptual understanding questions are not part of your final test and therefore, you are not going to be graded for it.

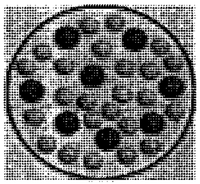
1. As shown A sample of **liquid ammonia** (NH$_3$) is completely evaporated (changed to a gas) in a closed container:

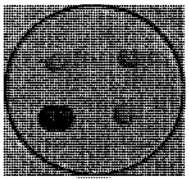


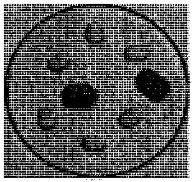
Which of the following diagrams best represents what you would "see" in the same area of the magnified view of the vapor?


A.


B.

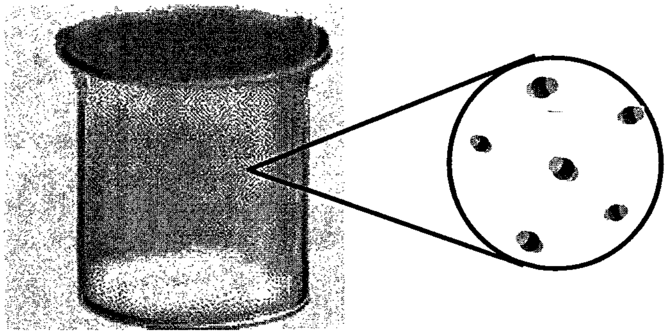

C.


D.

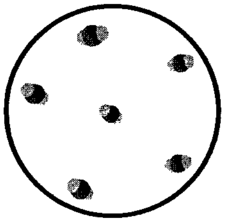

E.

Please elaborate and justify your reasoning. Identify any assumptions you are making.

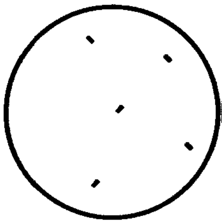
2. A magnified view of a sample of carbon dioxide (CO2) gas at a pressure of 1.0 atm is shown below.



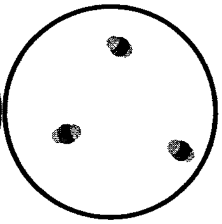
Which of the following diagrams best describes what you would “see” in the same area at a reduced pressure of 0.5 atm?



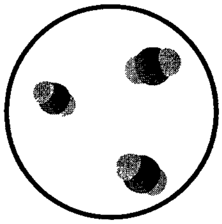
A.



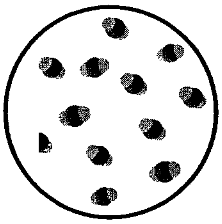
B.



C.



D.



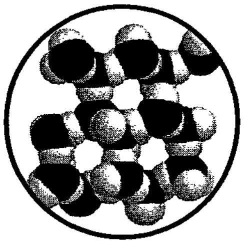
E.

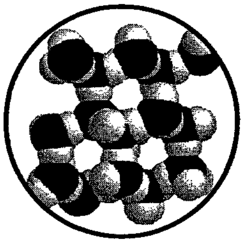
C is the answer.

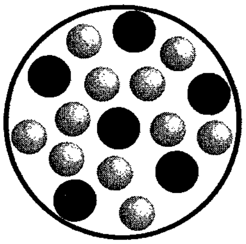
Please elaborate and justify your reasoning? Identify any assumptions you are making.

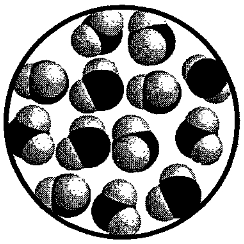
3. A diagram representing water molecules in the solid phase (ice) is shown below.

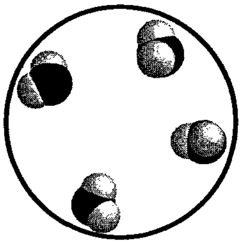
   Which of these diagrams best shows what water would look like after it melts (changes to a liquid)?

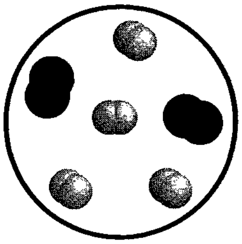



A.


B.


C.


D.


E.

C is the answer.

Please elaborate and justify your reasoning? Identify any assumptions you are making.

4. Consider three samples of water in three phases. The first is solid water (ice) at 0°C, the

second is liquid water at 24°C, and the third is gaseous water at 100°C. The water

molecules in the liquid phase __________ the water molecules in the gaseous phase.

A. move faster than
B. move slower than
C. move at the same speed as
D. move more randomly than
E. travel in the same direction as

B is the answer.

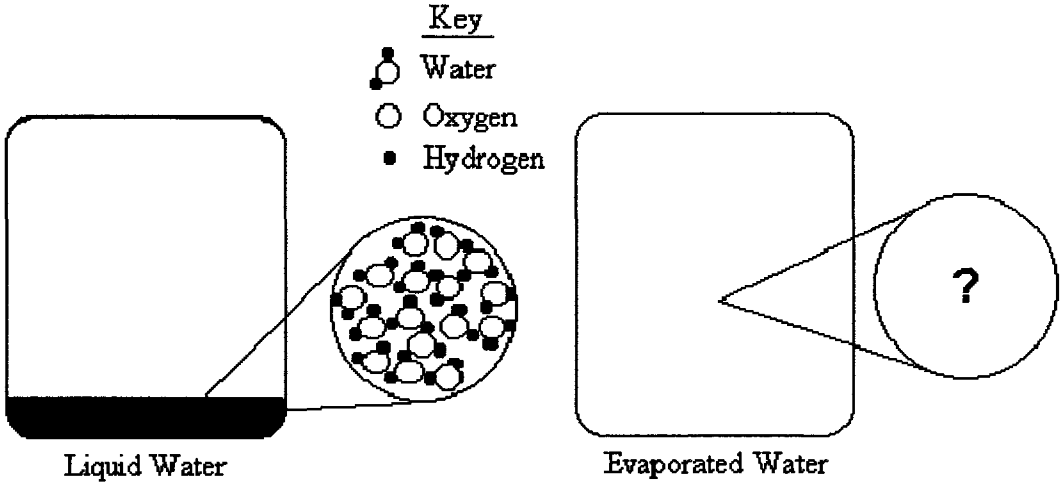
Please elaborate and justify your reasoning? Identify any assumptions you are making.

5. When water is vaporized, it is changed to
   - A. hydrogen and oxygen
   - B. hydrogen only
   - C. gaseous water
   - D. air, hydrogen, and oxygen
   - E. oxygen only

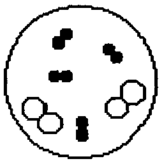
C is the answer

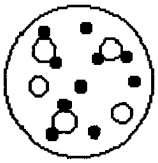
Please elaborate and justify your reasoning? Identify any assumptions you are making.

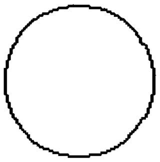
6. The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.

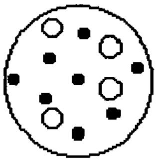


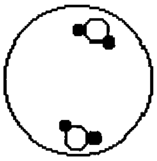
What would the magnified view show after the water evaporates?


(a)


(b)


(c)


(d)


(e)

E is the answer

How sure are you of your answer?

a) Very sure
b) Somewhat sure
c) My best guess.

APPENDIX B

SHRIGLEY'S ATTITUDE INSTRUMENT

You are to indicate your feelings toward the subject of science. You may react to the statements in one of the five ways:
A-Strongly Agree, **B**-Agree, **C**-Undecided, **D**-Disagree, **E**- Strongly Disagree

	SD	**D**	**U**	**A**	**SA**
1. I daydream during science classes.	1	2	3	4	5
2. I would like to have chosen science as a minor in my elementary education program.	1	2	3	4	5
3. I dread science classes.	1	2	3	4	5
4. Science equipment confuses me.	1	2	3	4	5
5. Science is not an important subject in the elementary curriculum.	1	2	3	4	5
6. I enjoy manipulating science equipment.	1	2	3	4	5
7. I am afraid that young pupils will ask me science questions that I cannot answer.	1	2	3	4	5
8. In science classes, I enjoy lab periods.	1	2	3	4	5
9. Science is my favorite subject.	1	2	3	4	5
10. If given the choice of student teaching, I would prefer teaching science over any other subject in the elementary school.	1	2	3	4	5
11. My science classes have been boring.	1	2	3	4	5
12. I would enjoy helping children construct science equipment.	1	2	3	4	5
13. When I become a teacher, I fear that the science demonstrations will not work in class.	1	2	3	4	5
14. I am looking forward to teaching science to elementary children.	1	2	3	4	5
15. I enjoy college science courses.	1	2	3	4	5
16. I prefer that the instructor of a science class demonstrate equipment instead of expecting me to manipulate it.	1	2	3	4	5
17. I would be interested in working in an experimental elementary science curriculum project.	1	2	3	4	5
18. I enjoy discussing science topics with my friends.	1	2	3	4	5
19. Science is very difficult for me to understand.	1	2	3	4	5
20. I expect to be able to excite students about science.	1	2	3	4	5
21. I frequently use scientific ideas or facts in my personal life.	1	2	3	4	5
22. Pre-supposing adequate knowledge about science, I would enjoy teaching the subject to children.	1	2	3	4	5
23. I believe that I have the same scientific curiosity as a young child.	1	2	3	4	5

Converted math ttitude statements to science attitude statements:
Figure 9.4, Tuckman (1999, p. 220)

The word "**math**" is replaced with the word "**science**"

1. Trying to do well in science class is awfully hard.
2. It scares me to have to take science.
3. I find science to be very interesting.
4. Science makes me feel secure.
5. My mind goes blank and I can't think when doing science. **(to replace #1)**.
6. Science is fascinating and fun.
7. Doing a science problem makes me nervous.
8. Studying science makes me feel uncomfortable and restless.
9. I look forward to going to science class.
10. Science makes me think I'm lost in a jungle of numbers and can't get out.
11. Science is something I'm good at.
12. When I hear the word science, I have a sense of dislike.
13. I like studying science better than studying other subjects.
14. I can't seem to do science very well.
15. I feel a definite positive reaction to science.
16. Studying science is a waste of time.
17. My mind is able to understand science.
18. I am happier in science class than in any other class.
19. Science is my most dreaded subject. **(to replace #3)**
20. I seem to have a head for science.

Revising the Science Attitude Scale
Cathy L. Thompson & Robert L. Shrigley (1986)

14. I am afraid that students will ask me questions that I cannot answer. **(to replace #7** in Shrigley's attitude Instrument).

APPENDIX C

INDEX OF LEARNING STYLES*

DIRECTIONS

Enter your answers to every question on the ILS scoring sheet. Please choose only one answer for each question. If both "a" and "b" seem to apply to you, choose the one that applies more frequently.

1. I understand something better after I

a) try it out.

b) think it through.

2. I would rather be considered

a) realistic.

b) innovative.

3. When I think about what I did yesterday, I am most likely to get

a) a picture.

b) words.

4. I tend to

a) understand details of a subject but may be fuzzy about its overall structure.

b) understand the overall structure but may be fuzzy about details.

5. When I am learning something new, it helps me to

a) talk about it.

b) think about it.

6. If I were a teacher, I would rather teach a course

a) that deals with facts and real life situations.

b) that deals with ideas and theories.

7. I prefer to get new information in

a) pictures, diagrams, graphs, or maps.

b) written directions or verbal information.

8. Once I understand

a) all the parts, I understand the whole thing.

b) the whole thing, I see how the parts fit.

9. In a study group working on difficult material, I am more likely to

a) jump in and contribute ideas.

b) sit back and listen.

10. I find it easier

a) to learn facts.

b) to learn concepts.

11. In a book with lots of pictures and charts, I am likely to

a) look over the pictures and charts carefully.

b) focus on the written text.

12. When I solve math problems

a) I usually work my way to the solutions one step at a time.

b) I often just see the solutions but then have to struggle to figure out the steps to get to them.

13. In classes I have taken

a) I have usually gotten to know many of the students.

b) I have rarely gotten to know many of the students.

14. In reading nonfiction, I prefer

a) something that teaches me new facts or tells me how to do something.

b) something that gives me new ideas to think about.

15. I like teachers

a) who put a lot of diagrams on the board.

b) who spend a lot of time explaining.

16. When I'm analyzing a story or a novel

a) I think of the incidents and try to put them together to figure out the themes.

b) I just know what the themes are when I finish reading and then I have to go back and find the incidents that demonstrate them.

17. When I start a homework problem, I am more likely to

a) start working on the solution immediately.

b) try to fully understand the problem first.

18. I prefer the idea of

a) certainty.

b) theory.

19. I remember best

a) what I see.

b) what I hear.

20. It is more important to me that an instructor

a) lay out the material in clear sequential steps.

b) give me an overall picture and relate the material to other subjects.

21. I prefer to study

a) in a study group.

b) alone.

22. I am more likely to be considered

a) careful about the details of my work.

b) creative about how to do my work.

23. When I get directions to a new place, I prefer

a) a map.

b) written instructions.

24. I learn

a) at a fairly regular pace. If I study hard, I'll "get it."

b) in fits and starts. I'll be totally confused and then suddenly it all "clicks."

25. I would rather first

a) try things out.

b) think about how I'm going to do it.

26. When I am reading for enjoyment, I like writers to

a) clearly say what they mean.

b) say things in creative, interesting ways.

27. When I see a diagram or sketch in class, I am most likely to remember

a) the picture.

b) what the instructor said about it.

28. When considering a body of information, I am more likely to

a) focus on details and miss the big picture.

b) try to understand the big picture before getting into the details.

29. I more easily remember

a) something I have done.

b) something I have thought a lot about.

30. When I have to perform a task, I prefer to

a) master one way of doing it.

b) come up with new ways of doing it.

31. When someone is showing me data, I prefer

a) charts or graphs.

b) text summarizing the results.

32. When writing a paper, I am more likely to

a) work on (think about or write) the beginning of the paper and progress forward.

b) work on (think about or write) different parts of the paper and then order them.

33. When I have to work on a group project, I first want to

a) have "group brainstorming" where everyone contributes ideas.

b) brainstorm individually and then come together as a group to compare ideas.

34. I consider it higher praise to call someone

a) sensible.

b) imaginative.

35. When I meet people at a party, I am more likely to remember

a) what they looked like.

b) what they said about themselves.

36. When I am learning a new subject, I prefer to

a) stay focused on that subject, learning as much about it as I can.

b) try to make connections between that subject and related subjects.

37. I am more likely to be considered

a) outgoing.

b) reserved.

38. I prefer courses that emphasize

a) concrete material (facts, data).

b) abstract material (concepts, theories).

39. For entertainment, I would rather

a) watch television.

b) read a book.

40. Some teachers start their lectures with an outline of what they will cover. Such outlines are

a) somewhat helpful to me.

b) very helpful to me.

41. The idea of doing homework in groups, with one grade for the entire group,

a) appeals to me.

b) does not appeal to me.

42. When I am doing long calculations,

a) I tend to repeat all my steps and check my work carefully.

b) I find checking my work tiresome and have to force myself to do it.

43. I tend to picture places I have been

a) easily and fairly accurately.

b) with difficulty and without much detail.

44. When solving problems in a group, I would be more likely to

a) think of the steps in the solution process.

b) think of possible consequences or applications of the solution in a wide range of areas.

APPENDIX D

INFORMED CONSENT

Study Title: The Effect of Learning Styles and Attitude on Pre-service Elementary Teachers' Conceptual Understanding of Chemistry and the Nature of Matter in A Simulation-Based Learning Environment.

Name of Researcher: Aljaroudi MO

You are invited to participate in a research project conducted through the University of Northern Iowa. The University requires that you give your signed agreement to participate in this project.

The study is designed to discover or establish how the learning styles of pre-service science teachers affect their ability to benefit from a hands-on and a simulation-based learning environment. By the end of this study, I hope to learn the effect of learning styles on student's conceptual understanding of the Nature of Matter in learning Liquids, Solids, and Gases in a simulation-based learning environment. I also will measure student's attitude towards science in the same learning environment.

You were selected as a possible participant in this study because you are college students who are taking Inquiry into Physical Science course as a required course to your elementary teaching science major. Also, I chose these classes because the students in Inquiry into Physical Science course use the hands-on and computer simulations-based activities.

You will have three items:

1. The science attitude instrument, consists of 23 questions, which will take approximately 10 minutes, and will given to you only one time in the beginning of this class.
2. The Learning Style Instrument (LSI), consists of 44 multiple choice questions, which will take approximately 15 minutes and will given to you only one time at the beginning of this class.
3. The Conceptual Understanding of the Nature of Matter test, consists of 6 questions, which will take approximately 15 minutes to answer. This test will be given to you twice: One at the beginning of the class, and the second one will be given to you at the end of the units.

If you agreed to participate, please complete the two surveys and answer the test in the third set of papers. It will take about 40-50 minutes total. You can also benefit from knowing what your learning style is, but will not be provided to you until the end of the study. You will be provided with contact information at the end of this paper. Your responses will be used to understand and assist elementary pre-service science learning

techniques, which will help curriculum designers to build curriculum that better fit students learning styles.
There is no risk associated with the participation in this study. There might be discomfort or inconvenience to you derives only from the amount of time taken to complete the Instruments and answer the questions.
Information that is obtained in connection with this study which could indentify you will remain confidential and will not be disclosed. The summarized findings with no identifying information may be published in an academic journal or presented at a scholarly conference.

Your decision whether or not to participate is voluntary, and will not affect your future career or affect your relationship with your class teacher or the University of Northern Iowa. If you decide to participate, you are free to discontinue participation at any time without any penalty or lose benefits to which you are otherwise entitled.
Please if you have any questions regarding this study, do not hesitate to ask. You may contact me later if you have any additional questions at (319-404-0162) or email me at (ma414019@uni.edu). If you have any questions about your rights, you can contact the office of IRB Administrator, University of Northern Iowa, at 319-273-6148.
Appreciate your cooperation.

Yours truly,

November 8, 2007

APPENDIX E

LETTER OF SUPPORT AND AGREEMENT

Dear Review committee,

We are writing this letter to indicate our support and agreement to allow Aljaroudi Mo to use approximately 50-60 minutes of our class time in the Spring 2008 sections of 820:031, Inquiry into Physical Science, twice during the semester (beginning and end) to administer his assessment instruments. Since class periods are 110 minutes on Mondays and Wednesdays, this arrangement can easily be accommodated.

Aljaroudi has met with us and discussed his project as indicated in his Human Participants Application section #3. As instructors, we will not provide any incentives to the students (such as class credit or extra credit) for participation, and students who opt not to participate in the study will not be penalized in any way and instead will be allowed to work on other class activities or leave class early while classmates complete the assessments.

If you have any further questions or comments, feel free to contact either of us.

Sincerely,

Dawn Del Carlo
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Jason Lang
Instructor,
Science Education
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