

USING INQUIRY-BASED INSTRUCTION WITH WEB-BASED DATA ARCHIVES  
TO FACILITATE CONCEPTUAL CHANGE ABOUT TIDES  
AMONG PRESERVICE TEACHERS

DISSERTATION

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By

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## ABSTRACT

The purpose of this mixed methods study was to describe and understand preservice teachers' conceptions of tides and to explore an instructional strategy that might promote the learning of scientific concepts. The participants were preservice teachers in three initial licensure programs. A total of 80 graduate students, in secondary, middle, and early childhood education programs completed a multiple choice assessment of their knowledge of tides-related concepts. Thirty of the 80 participants were interviewed before the instruction. Nineteen of the 30 students who were interviewed also participated in the instruction and were interviewed after the instruction. These 19 students also completed both the pre-test and 18 of them completed the post-test on tides and related content.

Data regarding the participants' conceptual understandings of tides were collected before and after the instruction using both qualitative and quantitative data collection methods. A multiple choice pre-test was developed by the researcher. The same test was used before and after the instructional intervention. Structured interviews were conducted with participants before and after instruction. In addition to interviews, participants were asked to write a short journal after instruction. The constant comparative method was used to analyze the qualitative data.

Preservice teachers' conceptual understandings of tides were categorized under six different types of conceptual understandings. Before the instruction, all preservice teachers held alternative or alternative fragments as their types of conceptual understandings of tides, and these preservice teachers who held alternative conceptions about tides were likely to indicate that there is one tidal bulge on Earth. They tried to explain this one tidal bulge using various alternative conceptions. After completing an inquiry-based and technology-enhanced instruction of tides, preservice teachers were more likely to hold a scientific conceptual understanding. Also, after completion of the inquiry-based and technology-enhanced instruction, some preservice teachers were likely to continue to hold the conception that the rotation of the moon around the Earth during one 24-hour period causes the tides to move with the moon. The findings of the study provide evidence that inquiry-based and technology-enhanced instruction utilizing Web-based archived data sources can be used to promoting conceptual change among preservice teachers.

Dedicated to my mother Leyla Ucar and  
my father Ali Ucar

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## CHAPTER 1

### NATURE AND SCOPE OF THE STUDY

#### Introduction

Most people are aware of daily astronomical events like phases of the moon and the rising and setting of the sun. Astronomy is one of the content areas of science in which students can make observations without special tools and without advanced professional training. Even though daily astronomical events are among the most common and easily observable natural phenomena, they also are among the most difficult to understand and the events most misunderstood by children and adults.

People usually develop their own mental models of easily observable astronomical events based on their everyday experiences (Vosniadou, 1991). These initial mental models generally are different from scientifically accepted models (Vosniadou & Brewer, 1992) and researchers refer to these understandings as alternative conceptions or misconceptions (Wandersee, Mintzes, & Novak, 1994). Identifying the major alternative conceptions that students and adults are likely to have and using this knowledge of alternative conceptions to develop instructional models and theories are areas that science educators have been dealing with for the last few decades. For example, researchers have

studied modifications of mental models (Vosniadou & Brewer), shifts of misconceptions into ontologically correct categories (Chi, Slotta, & Leeuw, 1994), and conceptual conflict (Hewson & Hewson, 1984). The outcomes of these efforts have been helpful in facilitating science instruction in schools and contributing to the national goal of developing a scientifically literate society (National Research Council [NRC], 1996).

The National Science Education Standards (NRC, 1996) promote teaching astronomy concepts in grades K-12. In grade levels 5 through 8, under the “Earth and Space Science” standards, the “Earth in the solar system” section focuses on astronomy for middle school students. Two of the specific concepts of “Earth in the solar system” are about predictable motions of celestial bodies; “Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses” (NRC, p.160-161), and gravity and its effects. The standards go on to state “Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion in the solar system. Gravity alone holds us to the Earth's surface and explains the phenomena of the tides” (NRC, p.160-161). These two standards require special consideration for this study because the literature indicates that students and teachers generally have a hard time understanding planetary motions and gravity and its effects, and they often have alternative conceptions about these phenomena (Atwood & Atwood, 1996; Atwood & Atwood, 1995; Baxter, 1989; Nussbaum, 1979; Sneider & Pulos, 1983; Trundle, Atwood, & Christopher, 2002; Viiri, 2000a; Vosniadou & Brewer, 1992, 1994).

Tides are an interdisciplinary concept as they are connected with astronomy, physics, geology, geography, and biology. While astronomy and physics tend to explain the physical mechanisms behind the causes of tides, other disciplines deal with outcomes of tides on the Earth and its organisms. Therefore, science educators should not ignore the content of tides because it integrates so many disciplines together. Thus, it is important that teachers and students have a good understanding of this concept.

This study, under the theoretical framework of Vosniadou's conceptual change model, investigated preservice teachers' conceptual understandings of tides before and after inquiry-based, technology-enhanced instruction. The relationship between understanding of tides and understanding of other astronomical events or phenomena (e.g., the shape of the Earth, phases of the moon, and gravitational forces between celestial bodies in relation to tides) was investigated. In addition, the relationship of using on-line data for scientific inquiry was investigated.

### The Purpose of the Study

The purpose of this two-phase sequential mixed method (Creswell, 2003) study was to describe and understand preservice teachers' conceptions of tides and to explore an instructional strategy designed to promote the learning of scientific concepts. Qualitative data were collected from a sub-sample of these preservice teachers to describe their understandings and any misconceptions they might have about tides. Quantitative data were gathered from the sub-sample and a larger sample of preservice teachers to explore their knowledge of tides. The qualitative and quantitative data were used to

describe and measure the potential impact of an inquiry-based, technology-enhanced instruction on the conceptual change process.

Preservice teachers' conceptual understandings of tides were explored using qualitative data gathering methods. Qualitative data were collected from a sub-sample of preservice teachers through interviews, which included structured questions, drawings, and the use of three-dimensional models. The models were made from three small styrofoam balls representing the Earth, sun, and moon. In addition to the qualitative data, an achievement test (quantitative instrument) was administered to measure the changes in this subset of preservice teachers' knowledge of tides before and after the instruction. The format of the test items included both multiple-choice questions and participants' drawings.

### Problem Statement

A review of misconception research indicates that both students and teachers hold alternative conceptions about a range of science topics, and it can be difficult to change these conceptions (Wandersee et al., 1994). Different conceptual change models provide explanations for the causes of alternative conceptions (Chi et al., 1994; diSessa, 1993; Vosniadou & Brewer, 1992) and these models offer suggestions about how to change the alternative conceptions and promote scientific understanding in science classrooms. For example, Vosniadou (1991) suggests that alternative conceptions occur as a result of conflicts between initial beliefs, which students gain through everyday experiences with the physical world, and the scientific explanation, which students are exposed to within

school. Vosniadou suggests that naive beliefs, or what she calls entrenched beliefs, constrain the scientific model and lie at the root of students' alternative conceptions.

Almost all children and adults have some experiences with different kinds of astronomical phenomena such as day and night, moon phases, seasons, and tides. Children usually bring their own ideas about easily observed astronomical events to the science classroom, and many people hold these initial ideas into adulthood (Driver, 1989). Students' conceptual understandings of astronomical phenomena have been studied broadly through science education research, and many papers focusing on people's understanding of different astronomical events have been published. These papers have mainly focused on: the shape of the Earth and Earth's gravity (Baxter, 1989; Mali & Howe, 1979; Nussbaum, 1979; Sneider & Pulos, 1983), causes of day and night (Atwood & Atwood, 1995; Vosniadou & Brewer, 1994), causes of seasons (Atwood & Atwood, 1996), and causes of moon phases (Trundle et al., 2002). Among astronomy topics, tides are an area that researchers have not investigated thoroughly. This is surprising because tides are specifically related to the phases of the moon and gravitational forces, and partially related to other astronomy concepts.

Tides are planetary phenomena. Therefore, they cannot be explained without taking into account other planetary bodies such as the sun and the moon (Viiri, 2004). In order to understand the tides, students need to understand the relationships between the Earth, the moon, and the sun. Tides are not only related to the Earth and the sun, they also are related to Newtonian mechanics, especially gravitational attraction and acceleration (Viiri, 2000a). Understanding tides requires a thorough understanding of gravity and of

the Moon-Sun-Earth system in three dimensional space (Hartel, 2000). Because understanding tides requires having a good understanding of other complex astronomy concepts (Taylor, Barker, & Jones, 2003; Viiri, 2004), it might be one of the most difficult topics in the K-12 science curriculum for students and teachers.

Tides are astronomical phenomena where causes and effects are misunderstood by many people (Galili & Lehavi, 2003; Viiri, 2000a). Many people would say that the moon causes the tides but they cannot explain the physical mechanisms behind it. The science education literature includes few studies that focus on students' and teachers' understandings of tides. In the science education domain, Viiri (2000a, 2004,) and Galili and Lehavi were among the few researchers who thoroughly investigated students' understandings of tides.

Viiri (2000a) realized that students have difficulties understanding high tides on the side of the Earth that faces away from the moon. Viiri discovered that, in general, students' understandings of tides were very poor. Galili and Lehavi (2003) investigated the importance of weightlessness and tides in teaching gravitation. They discovered that textbooks rarely mention tides and the textbooks that do mention tides use them to illustrate Newton's law of gravity. In their studies, both students and teachers failed to explain tides (Galili & Lehavi). Textbooks and instructional methods were stated as the major reason for the misconceptions related to the instruction of tides (Viiri). Hartel (2000) pointed out that there is difficulty in explaining tides when the explanation is restricted to print media. Based on this observation by Viiri and Hartel, it appears that

printed materials may not be effective and a new instructional design is needed for effective teaching of this complex astronomical phenomenon.

### Research Questions

This study specifically addressed the following research questions:

1. What are the types of conceptual understandings held by preservice teachers about the cause of tides?
2. What are the conceptual understandings held by preservice teachers about tides before completing an inquiry-based and technology-enhanced instruction including the study of tides?
3. What are the conceptual understandings held by preservice teachers about tides after completing an inquiry-based and technology-enhanced instruction including the study of the tides?
4. How do preservice teachers' types of conceptual understandings of tides differ after completing an inquiry-based technology-enhanced instruction including the study of tides?

### Significance of the Study

This research study contributes to the science education literature in three distinct ways. First, since it is one of the few studies which focus on preservice teachers' conceptual understandings of tides and the causes of tides, it fills a missing area in alternative conception research. More specifically, this study was designed to identify

alternative conceptions which have not been diagnosed in previous studies of students and preservice teachers. Curriculum developers, textbook writers, science teachers, science education researchers, and science researchers might make use of the findings of this research study for lesson planning, teaching, and future research.

Second, this study applies a new intervention for tides instruction, characterized as inquiry-based and technology-enhanced. The results of the study suggest a relationship between the inquiry-based and technology-enhanced instruction and construction of a scientific understanding of the causes of tides.

Third, this study described the relationship between the use of Web-based archived data for science instruction and the promotion of the conceptual change process. Preservice teachers used data sets from an original data source, which included actual data collected for scientific purposes. The effects of using these data for the tides instruction can provide a new perspective for science educators in terms of applying this strategy to other science content. Also, through use of this type of data, students would have the opportunity to do scientific inquiry in ways that are similar to how scientists conduct their work, which may be important for increasing positive attitudes toward science (Edelson, 2001; Songer, 1998).

#### Limitations of the Study

Limitations of the study come from several sources: using the same interview and test questions for both pre- and post-test data gathering; using models of the Earth, moon,

and sun which were not to scale; not having a random sample of subjects; and having only a one-sample design without a control group.

One limitation of the study comes from the use of identical questions for the pre- and post-interviews. Preservice teachers might have remembered the interview questions and paid more attention to material related to those questions during the instructional intervention. Therefore, they might have a better understanding of those specific questions and would answer accordingly during the post-interview. The same limitation is also a concern for the test items because the same test was used for the pre- and post-test. Retesting the individual with identical test questions is one of the major limitations of the measurement (Thorndike, 1997). Problems with this kind of design were specified by Gay (1996) as “subjects may learn something on the first test that helps them on the second ” (p.363). In addition, the interview might affect the preservice teachers’ responses to the test items because preservice teachers were provided some definitions during the interview in order to clarify the interview questions.

Using models during the interview could be another limitation of the study. The models used during the interview included the Earth, moon, and sun, which were not to scale in size or relative distance from each other. This scaling problem might have caused some misunderstanding of the distances and relative size in relation to the Earth, moon, and sun. Also, it is possible that some variation could be due to the differing of the subjects’ spatial abilities in terms of manipulating and understanding three dimensional objects with varied revolution and rotations at the same time.

Another limitation that might have impacted this study is the sample chosen. The participants were chosen because of their availability. Participants were all volunteers who received a small amount of cash as an incentive. Therefore, it was a convenience sample. Since it was not a randomly selected group, this sampling procedure decreases the generalizability of the findings. In addition to the sampling method, the size of the sample was not big enough to generalize the findings to the entire population. Besides the sampling and sample size issue, another factor was that the researcher was a graduate student in the same college as the preservice teachers. Personal relationships with participants might have affected the participants' responses to the interview questions and the tides achievement test. Moreover, participants were predominantly white females and mostly younger than 30-years of age. All of them were enrolled in a science methods course during the study.

Another limitation of the study was that the design involved only one group which was pre-interviewed and pre-tested, involved in the treatment, post-interviewed, and post-tested. This type of design is called "one-group pretest-posttest" by Gay (1996, p.326). The focus was to compare pre-test and post-test, pre-interview and post-interview, and describe the conceptual understandings before and after the instruction. Since there was not a control group for comparison, the study has limited potential for assigning cause and effect relationships.

The researcher was not a native speaker of English and that was one of the limitations of the study. Easton, McComish, and Greenberg (2000) identified several sources of drawbacks experienced by qualitative researchers during the data collection

and transcription. One of the validity issues related to the interviewing process and the transcription, according to Easton et al. (2000), includes making “mistakes in hearing or transcribing, inaccurate punctuation, misinterpreted words, being unfamiliar with slang terms” (Easton et al., p.706). Using a separate transcriber, who does not know the content and context, to transcribe the interviews may create a different set of problems. The researcher tried to avoid the issues related to having someone who does not understand the content by doing his own transcription. However, the researcher was a non-native English speaker, and this limitation applied to interviewing and transcription.

#### Definition of Terms

**Tides:** Daily fluctuations in ocean surface level throughout the day

**High Tides:** Highest point the water level reaches during tides

**Low Tides:** Lowest point the water level reaches during tides

**Spring Tides:** Difference between high and low tides is the greatest during spring tides.

High tides are very high and low tides are very low during spring tides. This occurs during new and full moon phases when the sun, the Earth, and the moon are aligned in a straight line. Gravitational forces of the sun and the moon add to each other during spring tides.

**Neap tides:** Difference between high and low tides is the smallest during neap tides. This occurs during the first and third quarter phases when gravitational forces from the sun and the moon do not add to each other.

**Mental models:** Explanation of the phenomena by the learner in response to the questions; It can be scientific or alternative

**Alternative conception:** An understanding which does not coincide with a scientific explanation; may be constructed through intuition or through instruction

**Technology-enhanced instruction:** Type of instruction which utilizes technology in the science lessons. In the current study, utilization of computers and their applications, such as Excel spreadsheets, simulations, and Internet connections, were used to access and analyze web-based archived data during the instruction. Web-based data were collected from an internet sources where tidal data were stored.

**Inquiry-based instruction:** Type of instruction which allows students to do scientific investigations in a way similar to what scientists do. Students apply science process skills, such as observing, predicting, generating and testing hypotheses, and accessing, analyzing, and interpreting data.

**Concept:** “All the knowledge a person has about a term. Thus a person might know that test tubes are made of glass, come in a range of sizes, stand in a rack, have stoppers, and are used to hold chemicals. There might also be images, visual ones of the appearance or haptic ones of the feel of a test tube being shaken in the hand, and episodes of experience, both generalized ones of boiling solution in test tubes, ‘popping’ hydrogen, or of pouring in and out of test tubes, and specific ones of a particular event in which, say, an accident led to a burn or a cut, or perhaps some remarkable reaction was observed. This collection of propositions, images and episodes, together with the skill of recognizing test tubes and

the motor skills of using test tubes in various ways, is the person's concept of 'test tube'"  
(White & Gunstone, 1989, p.577-578).

## CHAPTER 2

### LITERATURE REVIEW

#### Introduction

The purpose of this mixed method study was to understand and describe preservice teachers' conceptions of tides and to explore an instructional strategy that might promote the learning of scientific concepts. This chapter, a review of relevant research literature, is reported in three sections: Conceptual change models, which provided the theoretical framework for the study; the literature review on tides, which represented the targeted content in the study; and inquiry-based and technology-enhanced instruction, which provided the instructional strategy for the study.

#### Conceptual Change Model

##### *Historical Development of Conceptual Change Model*

A conceptual change model emerged from a constructivist teaching approach (Georghiades, 2000) and misconceptions research (Wandersee et al., 1994). The constructivist approach implies that in science classes students learn by making connections between their pre-existing knowledge and the new knowledge that they

construct during class (Gilbert, Osborne, & Fensham, 1982). Students' pre-existing knowledge allows them to be active learners rather than passive listeners. Misconception research, which also played a role in the emergence of the conceptual change model, arose from identifying students' and teachers' misconceptions (or alternative conceptions) in science. In one of the most comprehensive bibliographies on the subject, Pfundt and Duit (1988) listed 1400 references related to misconception research in science education. The overall findings of the misconception studies were summarized by Wandersee et al. (1994) in the Handbook of Research on Science Teaching and Learning. They composed eight major claims, which were:

1-Learners come to formal science instruction with a diverse set of alternative conceptions concerning natural objects and events.

2-The alternative conceptions that learners bring to formal science instruction cut across age, ability, gender, and cultural boundaries.

3-Alternative conceptions are tenacious and resistant to extinction by conventional teaching strategies.

4-Alternative conceptions often parallel explanations of natural phenomena offered by previous generations of scientist and philosophers.

5-Alternative conceptions have their origins in a diverse set of personal experiences including direct observation and perception, peer culture and language, as well as in teachers' explanations and instructional materials.

6-Teachers often subscribe to the same alternative conceptions as their students.

7-Learners' prior knowledge interacts with knowledge presented in formal instruction, resulting in a diverse set of unintended learning outcomes.

8-Instructional approaches that facilitate conceptual change can be effective classroom tools (p.195).

The findings on misconceptions research showed that both students and teachers have misconceptions, and it is difficult to make progress toward a scientific understanding. Misconception research does not tell us much about how to promote a scientific understanding. Rather the function of this body of research is to present identified misconceptions. At this point, the need for promoting a scientific understanding triggered the emergence of the conceptual change model. Research in science education started to shift from the collection and identification of misconceptions toward looking for instructional interventions that could be utilized to reconstruct knowledge and promote scientific understanding.

The Conceptual Change Model has been one of the most applied theories in science education since the early 1980s. It has been broadly studied from the science education perspective (Beaujardiere et al., 1997; Beeth, 1998a; Driver, 1989; Hewson, 1981; Hewson & Thorley, 1989; Mortimer, 1995; Nussbaum, 1989; Pintrich, Marx, & Boyle, 1993; Posner, Strike, Hewson, & Gertzog, 1982; Thagard, 1991; Treagust, Harrison, & Venville, 1996; Tyson, Venville, Harrison, & Treagust, 1997; Venville & Treagust, 1996; Vosniadou & Brewer, 1992) and from the cognitive science perspective (Carey, 1988; Chi & Slotta, 1993; diSessa, 1993; Slotta, Chi, & Joram, 1995; Vosniadou & Brewer, 1992, 1994; Wiser & Carey, 1983).

Conceptual change study first appeared in the early 1980s with the work of Posner et al. (1982). Even though it seemed that this was the first appearance of the conceptual change model, other researchers in the area of history and philosophy of science (Kuhn, 1970; Lakatos, 1970; Piaget, 1964) mentioned the conceptual change

process in their studies, although they did not use the term *conceptual change*. Kuhn and Lakatos looked at the conceptual change model from the science perspective, specifically how science progressed and how scientists actually did science. Kuhn used the word “paradigm shift” to describe his model of how science progresses. According to Kuhn, scientists ascribe to a certain paradigm and conduct science in that paradigm. Normal science is conducted in this paradigm until an anomaly arises. After that point, scientists start to search for explanations to resolve the anomaly. If the problems that stem from the anomaly in the current paradigm cannot be resolved, scientists consider shifting the paradigm, which is also called a scientific revolution. In Lakatos’ theory, science is conducted around a “theoretical hard core” (p.133), which generates a research program designed both to apply this hard core and to protect it from attack. Lakatos indicated that science progresses by replacing an old research program with a new one when the theoretical hard core is under attack. Both Kuhn and Lakatos were philosophers who inspired conceptual change research.

### *Initial Conceptual Change Model*

According to Vosniadou (1999), conceptual change research in science education was developed independently from conceptual change research in the cognitive science disciplines. Conceptual change theory, developed by Posner et al. (1982) and expanded by Hewson (1982), has been one of the most influential theories in science education research. Posner et al.’s theory was based on the analogy between construction of individual scientific understanding and the development of scientific theories (Tyson et

al., 1997). This theory was based on science philosophers' work, such as Kuhn (1970) and Lakatos (1970), and developmental psychologists like Piaget (1964). Posner et al. indicated that assimilation and accommodation were two kinds of conceptual change processes. Assimilation was defined as using existing concepts to deal with new phenomena. In other words, assimilation meant integration of new concepts with pre-existing concepts without any conflict with the pre-existing concept. However, sometimes students' current concepts were inadequate to grasp new phenomena. Subsequently, new phenomena may not fit into the existing conceptual structure. In this kind of situation, students must replace or reorganize their central concepts. This was called radical conceptual change or accommodation (Posner et al.). Accommodation does not occur when the concept can be assimilated (Strike & Posner, 1992). If the learner can make a meaningful connection between new and old concepts, no conflict arises, and thus the learner does not have to perform accommodation.

Conceptual change processes included two major components: conditions for accommodation and conceptual ecology.

#### *Conditions for Accommodation*

Four conditions were described by Posner et al. (1982) for conceptual change to take place. Those conditions are, respectively: dissatisfaction, intelligibility, plausibility, and fruitfulness.

The first condition needed for conceptual change to take place is dissatisfaction. Neither scientists nor students make any major changes in their concepts unless they are

dissatisfied with the existing concepts. In other words, learners need to realize that their current theory is not providing solutions to the problems (Posner et al., 1982). Unlike Posner et al., Hewson and his colleagues (Hewson, 1982; Hewson & Lemberger, 2000; Hewson & Thorley, 1989) defined dissatisfaction not as a first condition for accommodation, but as the last condition. Hewson and Lemberger argue that “dissatisfaction with current conceptions arise when people recognize that they (the current conceptions) are not as plausible or as fruitful as originally thought” (p.110). The second condition for accommodation is intelligibility, which means that the learner must find new concepts intelligible (Posner et al., 1982). The new concepts must make sense to the learner. Otherwise, a concept cannot be incorporated into the existing conceptual ecology. The only way to incorporate an unintelligible concept into a conceptual ecology is to memorize it (Hewson, 1981). A person can find a new conception intelligible but it is possible that this person does not believe this concept is valid (Hewson ; Posner et al.). Intelligibility does not mean that the concept is believable. The third condition for accommodation is plausibility. The new concepts must at least appear to have the capability to solve the problems which were not solved with previous concepts (Posner et al.). Consistency of the new concepts with each other is a sign of plausibility. The prerequisite to plausibility is intelligibility (Hewson). If a concept is not intelligible, it cannot be plausible. The last condition for accommodation is fruitfulness, which means that the new concept should have the potential to be applied to other areas in order to find solutions to different problems (Hewson ; Posner et al.). Prerequisites for being fruitful

are that the concept must be intelligible and plausible to the learners. Otherwise, it cannot be fruitful.

### *Conceptual Ecology*

According to Hewson and Hewson (1984), the intellectual environment in which a person lives provides the conditions to develop some concepts and restrains the development of others. Hewson said “intellectual environment acts as an ecological niche” (p.5). Posner et al. (1982) called an individual’s current concepts conceptual ecology, which was a term borrowed from Stephen Toulmin (Posner et al.; Toulmin, 1972). All learning activities and inquiry occur in the framework of an individual’s conceptual ecology. Thus, conceptual ecology involves a dynamic interaction between a person’s knowledge structures and the intellectual environment in which that person lives (Hewson & Hewson, 1984).

The conceptual ecology of an individual consists of many different kinds of features, such as anomalies, analogies and metaphors, epistemological commitments, metaphysical beliefs, and other knowledge (Posner et al., 1982). These five features of conceptual ecology are related to the conditions of conceptual change in terms of difficulties students have. The five features of the conceptual ecology were later expanded by Strike and Posner (1992) to include exemplars, images, and past experiences. Posner et al. pointed out two pedagogically interesting aspects of the features of conceptual ecology. First, they provide a record of the kinds of information that learners are likely to have and that must be taken into account by teachers. Second,

teachers might provide those features in instruction in order to promote conceptual change. By not providing those features in the instruction teachers do not consider students' preexisting knowledge and experiences.

### *Student as a Scientist*

Posner et al. (1982) built an analogy between students and scientists when they applied the theories of Kuhn (1970) and Lakatos's (1970). Posner et al. found it fruitful to treat the students engaged in learning science as practicing scientists. This approach has been criticized extensively for several reasons. First, it was critiqued because the scientist is a member of a broader scientific community and scientists' interactions with the scientific community helps the scientist to grow his/her enterprise (Caravita & Hallden, 1994). In the same sense, it is argued that students are part of a learning community where they can interact and grow their enterprises as scientists do. However, age and intellectual capacity, past experiences, prior knowledge, and amount of time devoted to studying a subject by students are far different than those of a scientist (Carey, 1988; Nussbaum & Novick, 1982).

Second, the student's metacognitive awareness is greatly different from that of the scientist. The scientist's metacognitive awareness allows him/her to produce alternative strategies and deal with the anomalies, whereas the student usually does not (Ioannides & Vosniadou, 2001).

Third, Vosniadou and Brewer (1987) thought that "restructuring in the case of a scientist requires the discovery of an internally consistent new paradigm" (p.55).

However, children cannot discover a new paradigm. Instead, children integrate their scientific view, which comes from experience with the scientific view that is provided by the teacher (Carey, 1994).

Fourth, scientists who develop theories are always among the best educated people of their times with the most advanced mathematical tools and knowledge of scientific achievements (Carey, 1988). Students, conversely, do not have the knowledge and background that scientists have.

The notion of “student as a scientist” is usually rejected by the researchers who focus on the cognitive aspects of science learning (Carey, 1988; Vosniadou & Brewer, 1987; Wiser & Carey, 1983), but was accepted by science education researchers (Beeth, 1998b; Chinn & Brewer, 1993; Hewson, 1981; Posner et al., 1982). The reason for this discrepancy appears to be that science educators focus on the instructional aspects of conceptual change while cognitive scientists focus on the individual’s personal reactions in a specific situation. Instruction requires student engagement with the task and mimicking the scientist seems to be the best practice.

### *Revision of the Conceptual Change Theory*

In 1992, Strike and Posner revised their original conceptual change theory because it was criticized due to its overemphasis on rational aspects of learning and inadequate emphasis on the importance of affective and social issues for conceptual change. Specifically, it focused only on students’ cognition without paying any attention to motivational beliefs and students’ roles in the classroom learning situation (Pintrich et

al., 1993; Venville & Treagust, 1998). In the revised theory, Strike and Posner (1992) added the following modifications into the initial conceptual change theory:

1. A wider range of factors need to be taken into account in attempting to describe a learners' conceptual ecology. Motives and goals and the institutional and social sources of them need to be considered.
2. Current scientific conceptions and misconceptions are part of the learner's conceptual ecology. Thus they must be seen in interaction with other components.
3. Conceptions and misconceptions can exist in different modes of representation and different degrees of articulateness.
4. A developmental view of conceptual ecologies is required.
5. An integrationist view of conceptual ecologies is required. (p.148).

Their new emphasis was on motivation, misconception, and conceptual ecology.

They point out that all parts of conceptual ecology, including both scientific conceptions and misconceptions, must be perceived as dynamic development (Strike & Posner, 1992).

Another interesting point in the revised theory was the notion that misconceptions may not necessarily preexist but “may be generated on the spot as a consequence of instruction” (p. 158). This was an important point because it indicated that students sometimes develop different concepts from those that they are taught in school.

### *Conceptual Capture and Conceptual Exchange*

Peter Hewson was one of the researchers who was involved in the development of the first conceptual change model with Posner et al. (1982). The conceptual change model was later extended and clarified by Hewson (1982), in terms of the emphasis on the status of conditions for accommodation, addressing students' prior knowledge in the instruction, and the use of cognitive conflict to increase the status terms. Posner et al. used the terms assimilation and accommodation and acknowledged that these were the

Piaget's terms, but indicated that in using them, Posner et al. pledged no commitment to Piaget's theory. Hewson preferred to use the terms "conceptual capture" and "conceptual exchange" for assimilation and accommodation, respectively, for two reasons: First, he wanted to eliminate any confusion with Piaget's terms, and second, he felt that the dictionary definitions of conceptual exchange and conceptual capture gave a clearer sense of what he meant. Conceptual capture occurs when the newly presented concept is reconciled with the old concepts, while conceptual exchange occurs when the new concept replaces the old one.

Conceptual ecology and the conditions for conceptual exchange (dissatisfaction, intelligible, plausible, and fruitful) were the two major components in Hewson's (1982) conceptual change model. Both conceptual ecology and the conditions for conceptual exchange were described earlier when the Posner et al. (1982) model was introduced. Those definitions also apply to Hewson's studies. Thus, conceptual ecology and status will not be redefined here. The main difference between the Hewson and Posner et al. models was the order of dissatisfaction in the sequence of conditions (Hewson). Posner et al. indicated that the first condition for accommodation was dissatisfaction, in which the learner has to become dissatisfied with the existing concepts. This is perceived when the existing conception does not answer the potential problems. On the other hand, Hewson indicated that dissatisfaction comes last in accommodation. In order for a learner to be dissatisfied they are first presented with a new conception, and if the new conception increases in status while the old conception decreases in status, dissatisfaction with the existing conception occurs.

Increasing or decreasing the status of a conception determines whether a conceptual exchange will occur (Hewson, 1982; Hewson & Thorley, 1989). The status of a person's conception is the extent to which the conception meets the three conditions of intelligibility, plausibility, and fruitfulness (Hewson & Hennessey, 1992). The more conditions that a conception meets, the higher is its status. The status of the concept is lowered if there is dissatisfaction with the existing concept, and the status of the new concept rises if the reasons for dissatisfaction are removed (Hewson). This sequence of the status was clarified by Hewson (1981), with the statement, "a conception cannot be fruitful without being plausible, and cannot be plausible without being intelligible" (p. 389). Thus, being intelligible is the first condition that needs to be fulfilled. If the concept is not intelligible, it can not replace the old one except through memorization.

Dissatisfaction with an existing concept can occur under three conditions (Hewson, 1982): "(a) if the reanalysis of experience shows that the existing conception is no longer necessary, (b) if existing conception is seen to be irreconcilable with new knowledge which cannot be ignored, and (c) if existing conception violates some epistemological standards" (p. 65). When these conditions occur, the status of existing concepts is lowered. Lowering the status of an existing condition does not simultaneously raise the status of alternative conditions. Alternative conditions first have to be intelligible, and then plausible and fruitful, in order to rise in status.

As far as instructional strategy, Hewson mainly used two kinds of methods; first, he explicitly addressed students' alternative conceptions (Hewson, 1982), and second, he applied conceptual conflict (Hewson & Hewson, 1984) to lower the status of existing

concepts and raise the status of the new concepts. In both methods, he discovered that the status of a new concept can be elevated.

Historically, his method did not change much through time. He stayed with the initial conceptual change models, except in his sequence of dissatisfaction. He has analyzed the status of the conditions since the early 1980s. The only change in his methodology was that, at first, he explicitly addressed the misconceptions, and later he applied cognitive conflict and anomalies in his research as an instructional strategy.

### *New Perspectives on Conceptual Change*

#### *Role of Motivation*

In the initial conceptual change model, Posner et al. (1982) did not pay attention to factors other than the status of concepts and how this status changed. This shortcoming of the model was addressed in its revision, in which Strike and Posner (1992) accepted that the motivational factors and social interactions in the classroom were noteworthy components of conceptual change. The importance of motivation has been addressed by many different researchers (Caravita & Hallden, 1994; Pintrich et al., 1993; Vosniadou, 2001b). Among these, Pintrich et al. did the most extensive analysis of the role of motivational factors in conceptual change. Pintrich et al. proposed several motivational constructs as potential mediators for conceptual change. Among those constructs, “goals” and “self-efficacy” are given a more significant role in the conceptual change process.

The goals identified by the motivation theory are to guide students’ learning and engagement in science classrooms (Pintrich et al., 1993). Pintrich and colleagues focused

on two types of goals: mastery orientation and performance orientation. The difference between mastery and performance orientation was that students who adopt mastery orientation focus upon learning, understanding, and mastering the task. On the other hand, students who adopt performance orientation focus on obtaining a good grade or performing the best in the class. Pintrich et al. wrote, “Students who are focused on the task with a learning/mastery orientation are more likely to process information in a way that increases the probability that four conditions necessary for conceptual change will occur” (p.177). It could be inferred from that statement that students who adopt a performance orientation tend to memorize the task.

Self-efficacy, which is the students’ beliefs about their capacity to accomplish a task, is another aspect of motivational beliefs addressed by Pintrich et al. (1993). How to see self-efficacy in a conceptual change model was defined in two different ways by Pintrich et al. The first way was that self-efficacy shows itself in conceptual change processes as students’ confidence in their own ideas and conceptions shifts. Students’ high confidence could be problematic in that higher levels of self-efficacy or confidence would be a hindrance in conceptual change. It can be hard to give up previous conceptions and to accommodate new ones if students have high confidence in their existing concepts. The second way was that students gain confidence to change their ideas. In other words, self-efficacy would give students confidence in gathering evidence, hypothesis testing, prediction, and considering alternative models.

### *Metacognition and Conceptual Change*

The importance of metacognition has been addressed by some researchers since the appearance of the conceptual change models (Beaujardiere et al., 1997; Beeth, 1998a; Georghiades, 2000; Vosniadou & Ioannides, 1998). Vosniadou and Ioannides point out that conceptual change involves the students' metaconceptual awareness. They indicated that a student's ability to learn science concepts depends upon whether or not the students are aware of their metaconceptual views. White and Gunstone (1989) supported the importance of metacognition by stating, "if metalearning can be taught, then the problem of how to bring conceptual change may be solved" (p.581).

White and Gunstone (1989) looked at the conceptual change model as describing a process for abandoning the old belief and accepting the new one. In their perspective, promoting a new belief is easy but abandoning the old one is much more difficult. They proposed metalearning to find a solution to this problem. They formulated several principles related to the development of metalearning in science learning. Some of those principles were context, learner's understanding of purpose, importance of collegial support, outside support to facilitate change in teaching strategies, variations in teaching strategies, personal motivation, and support for long-term rather than short-term goals. These principles play a significant role in the conditions of conceptual change, especially the condition of dissatisfaction with the old conception.

In a study with 5<sup>th</sup> grade students, Georghiades (2000) applied metacognitive instruction in order to investigate the relationships between metacognitive instruction, transfer, and durability. In the metacognitive instruction group, students were reflective

about their learning. They made connections between prior and current conceptions and were aware of analysis and difficulties of the task by using their own language. He found that metacognitive instruction was possible with this grade level. In other words, children in this age group were capable of reflecting upon their learning within the limitation of their mental and cognitive development. Another finding of this study was that metacognitive instruction was best given in small groups, not within whole-class instruction, because students feel more comfortable expressing their metacognitive thoughts to small groups rather than to the whole classroom. In addition, small groups allow children more opportunities for participation in discussion, record keeping, and other activities. Lastly, children who received metacognitive instruction performed better in terms of understanding the concept than the other instruction group. In conclusion, this study showed that “metacognitive instruction within conceptual change learning should be considered as a potential mediator of improvement” (p.135).

Beeth (1998a) used the status of conception as a metacognitive tool in order to foster conceptual change. The term “status” was used first by Hewson (1981) to refer to conditions for accommodation. In other word; status of a concept was the degree of fulfilling the conditions. For example, no status meant the concept was not intelligible, plausible, or fruitful, while high status meant the concept was intelligible, plausible, and fruitful (Hewson & Hewson, 1984). The status of a concept can either ascend or descend. Thus, the higher the status of a concept is, the higher the possibility that accommodation would occur (Hewson & Thorley, 1989).

In Beeth's (1998a) study, teachers and students negotiated definitions of status terms and students were expected to use those status terms when discussing science concepts. The meanings of status terms, such as intelligible, plausible, and fruitful, were introduced to the students on a topic which students were familiar with, and then these students were expected to apply the terms to content with which they were not familiar. In Beeth's study, the unfamiliar content was force and motion. The purpose of the study was to investigate how teachers and students negotiate definitions for status terms, and how students apply their understandings of status terms when learning new science concepts.

Beeth (1998a) discovered that students in this classroom were able to define the status terms intelligibility and plausibility, and students applied both status terms effectively when they talked about the new content, force and motion. Using status terms provided the students the opportunity to reflect metacognitively on their own conceptions and how they learned these new concepts. This metacognitive reflection was also valuable to the teachers, because they had the opportunity to see their students' progress and plan the instruction accordingly. Another advantage of using the status constructs of intelligibility and plausibility was that students understood both their own ideas and those of their classmates. Because of its time-consuming nature, this approach of defining status terms was not practical to implement in a regular classroom environment, but Beeth did show that facilitating metacognitive discussions helped students communicate more effectively about their ideas and the ideas of others. In addition, it enabled them to experience the conceptual change.

Another interesting finding reported by Beeth (1998a) was in regards to the relationships between teachers and students. The teacher's role in this study was different than the traditional teacher's role, which consists of organizing and sequencing content. In this study, the teacher was able to play a more dynamic role in answering the students' content questions and addressing their metacognitive abilities. Thus, metacognitive instruction changes both teachers' and students' roles and practices in the classroom.

Georghiades' (2000) metacognitive instruction and Beeth's (1998a) status construct study support each other in two ways. First, both found that applying metacognitive approaches to science education helps the students increase their abilities and foster a more effective understanding of the content. Second, both studies showed that it is difficult to implement a metacognitive approach in large classrooms. Even though metacognition is a powerful tool, more work needs to be done to make this approach more applicable in regular classroom settings.

### *Analogy*

Analogy is described by Posner et al. (1982) as one of the factors which comprise a learner's conceptual ecology. Analogy is based on the symmetry between base and target (Duit, 1991). Base is defined as the learner's already-known phenomena. For example, a water hose could be a base if the content is teaching electrical current flowing through the wire, which is the target. Target is the unknown phenomena, which is the desired knowledge, or the knowledge that students expect to have after instruction (Clement, 1993). Analogy is a key process in the constructivist learning approach

because students learn the content by constructing the similarities between their pre-existing knowledge and new knowledge (Duit, 1999).

Treagust et al. (1996) conducted a study by using analogy to teach refraction of light as it passes from a less-dense medium into denser medium to 38 tenth-grade students. They found out that using an analogy to teach refraction engendered conceptual change. However, the authors could not determine “whether the analogy contributed to conceptual change or whether the analogy merely provided students with a means to express themselves with language which was otherwise unavailable to them” (p.227). In another study, Venille & Treagust (1996) found that analogies play many different roles in conceptual change, such as “sense maker, memory aid, transformer, and motivator” (p.316). The idea that analogy is a “sense maker” supports the notion that analogy might help students to discover a new way to express their thoughts.

Another approach to teaching by analogy, called bridging analogy, was investigated by Clement (1993). He used more than one analogy as steps to reaching the target. In this model, an intermediate analogy that shares features with both the base and the target was called a bridging case. For example, the book resting on a flexible board shares some features of the book on the table and some features of the spring. The book on the flexible board is the bridging analogy that shares similarities with both the book and the spring. He found that this is an effective method to teach target concepts, but it requires more time because students need to be convinced of the validity of this chain.

Even though analogies play an important role in the conceptual change process (Duit, 1999; Duit, Roth, Komorek, & Wilbers, 2001; Thagard, 1992), they do not always

facilitate conceptual change because students do not always understand analogies in the same way intended by teachers and textbooks (Duit). Students sometimes do not see the analogies at all or they develop different analogies altogether (Duit et al.).

### *Cognitive Conflict*

Dissatisfaction, which is the first condition for accommodation, was introduced by Posner et al. (1982) in the initial conceptual change model. In the Posner et al. conceptual change model, misconceptions held by the student would be replaced or extinguished if the four conditions were met. This led some researchers to develop instructional strategies based on conceptual conflict, which is designed to foster dissatisfaction and remove alternative conceptions (Hewson & Hewson, 1984; Nussbaum & Novick, 1982).

Nussbaum and Novick (1982) proposed a teaching strategy which consists of three phases. In the first phase, students invoke their alternative conceptions in order to interpret them. They are encouraged to state their preconceptions verbally and pictorially. Teachers try to help students become aware of their own alternative conceptions. In the second phase, a discrepant event is presented to create a conflict between exposed preconceptions and some observed phenomena which the students can not explain. And in the third phase, students are encouraged to search for solutions and promote emerging accommodation. The authors found that conceptual conflict enhanced accommodation in this science class. The findings of this study are problematic in two ways. First, pushing students to be aware of their own alternative conceptions might already make some

students realize the scientific conceptions, and second, students might try to explain the anomalies within their current conceptual understandings. In addition, students could possibly develop additional alternative conceptions.

Limon (2001) identified some challenges to cognitive conflict. The first problem she identified was how to make cognitive conflict meaningful for students.

“Motivational factors, epistemological beliefs, prior knowledge, values and attitudes, learning strategies and cognitive engagement, and reasoning strategies, as well as social factors, seem to be relevant to lead students to a meaningful conflict” (p.374). The second problem she identified was related to the implementation of the cognitive conflict strategies in school settings; cognitive conflict strategy requires more time and effort than other strategies.

Using cognitive conflict does not seem to be a good way to foster conceptual change even though studies showed that it is an effective strategy. Misconception research (Wandersee et al., 1994) showed that misconceptions were usually resistant to change with instruction. Also, another study (Vosniadou & Brewer, 1992) showed that students’ initial conceptions are consistent and provide them with the explanation for the phenomena. Because of these two reasons, cognitive conflict strategy does not seem to be an effective way to change student conceptions. Students would resist changing their misconceptions because they have a structured understanding of the phenomena.

### *Knowledge in Pieces*

diSessa (1993) investigated the conceptual change process from a different perspective than Posner et al. (1982). His starting point was to question what the elements of knowledge are, how they arise, if they are systematic, and how they evolve. He conducted a series of clinical interviews with undergraduate physics students trying to solve a set of specially designed problems, which provide the empirical evidence for his theory.

He indicated that intuitive physics is the content that should be investigated first. Everyday experiences in the physical world play a major role in building intuitive knowledge. According to diSessa (1988), “intuitive physics is a fragmented collection of ideas, loosely connected and reinforcing, having none of the commitment or systematicity that one attributes to theory” (p.50). He calls these fragments phenomenological primitives or “p-prims.”

In his extensive study, diSessa (1993) gave detailed definitions of the p-prims and identified some p-prims in physics. diSessa also identified major characteristics of p-prims. For instance, p-prims are rather “small knowledge structures.” Thus, they cannot explain any phenomena by themselves. They are self explanatory and they do not need any justification. P-prims should not be confused with concepts or beliefs. They are much smaller sub-conceptual pieces of knowledge. Some p-prims are more important than other p-prims. Some tell us more about phenomena than others. There are lots of p-prims in the physical world but they do not exhibit deductive relations or any other systematic connections. Describing the p-prims in words is difficult because they are not words or

word senses, and are not encoded linguistically. And lastly, p-prims are not extinguished or replaced by learning scientific concepts.

In his earlier studies, diSessa (1993) explained the conceptual change process as development from naïve to expert physical intuition. Learners first collect rather large but relatively unstructured p-prims as they progress toward becoming experts. Then, they organize those unstructured and fragmented p-prims toward a structured and organized system. This organization is not a quick one-step process. Novice learners first organize the p-prims into small structures, and then these small structures are organized into larger structures. This process continues until a coherent, well-structured explanation is produced.

In a later work, diSessa and Sherin (1998) proposed another model for science learning. They proposed a new term “coordination class” (p.1171) to explain what a concept is and how knowledge is organized. In his previous explanation, diSessa did not talk about concepts, but instead focused on p-prims. In addition, diSessa distinguished those p-prims as not concepts, but subconceptual pieces of knowledge. diSessa and Sherin defined coordination classes as “systematically connected ways of getting information from the world” (p.1171). The underlying construct in this definition was that diSessa tried to define concepts as categories, relational theories, or patterns (diSessa & Sherin). However, those definitions did not satisfy him so he defined a set of characteristics which concepts should have. He expected certain characteristics from a model of a concept, such as analytic clarity, different varieties, hierarchy, and ability to match real-time data. Those characteristics of a concept were included in the coordination

classes. He did not call coordination classes concepts, but used the coordination classes instead of concepts. In conclusion, p-prims are the small fragments of coordination classes which are a larger and more complex system than p-prims. When coordination classes come together, they construct a theory (diSessa, 2002). The relationships between p-prims, coordination classes, and other concepts can be seen in Figure 2.1.

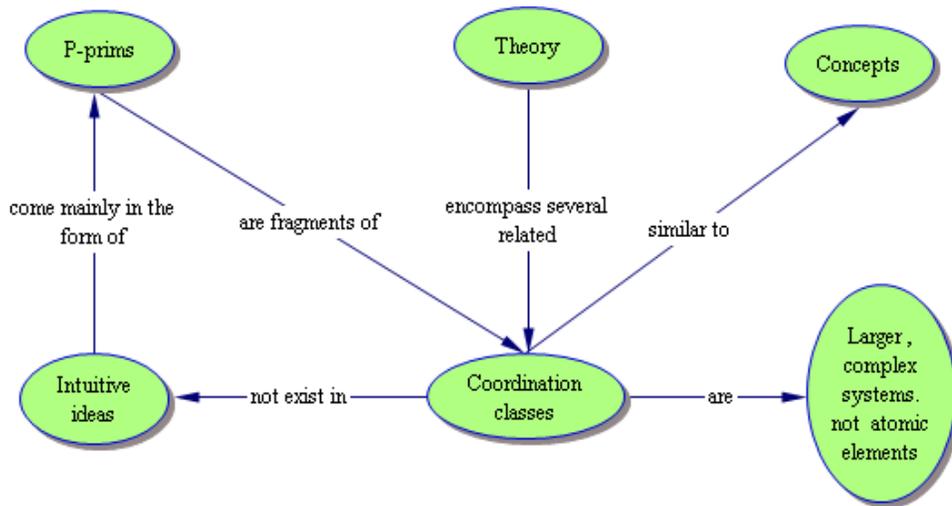


Figure 2.1: Relationships between p-prims, coordination classes, and other concepts in diSessa's model.

This model, developed by diSessa, does not seem much different from Piaget's developmental theory. Organizing p-prims or coordination classes resembles assimilation, in the sense that assimilation is the "integration of any sort of reality into a structure" (Piaget, 1964, p.17). In other words, it is the organization of the knowledge

system including the new information. Piaget did not specify the characteristics of realities. It can be assumed, however, that he meant that any kind of information, regardless of the size of p-prims or concepts or coordination classes, could be a reality. Thus, organizing those realities to make sense of them seems similar to what diSessa argues.

Unlike diSessa, some researchers who focus on cognitive aspects of learning (Chi & Slotta, 1993; Ioannides & Vosniadou, 2001) think that children organize some of their experiences in narrow but relatively coherent frameworks and construct specific theories in their attempt to make sense of the physical world. These researchers also emphasized the fact that the process of learning involves enrichment of the initial knowledge. Initial knowledge is reorganized and restructured as children are exposed to school science. According to Vosniadou, children do not need to wait for systematic instruction to organize that information (Vosniadou & Kolloas, 2003). Another distinction of diSessa's theory is that he implies that intuitive knowledge is developed into formal physics knowledge (Chi & Slotta). He did not note any possibility that intuitive knowledge can grow into misconceptions. Vosniadou and Brewer (1992) previously stated that students' intuitive ideas might develop into misconceptions when students are exposed to science instruction. Thus, organizing the p-prims might not always result in correct scientific understanding of the phenomena.

### *Ontological Categories*

Ontological categories were the main starting point in Chi et al.'s (1994) conceptual change model. According to Chi et al., all entities in the world can be placed into one of three different ontological categories. These three primary ontological categories are: "matter, processes and mental states" (p.29). Those three major categories have their own subcategories, which are hierarchically organized in a tree-like structure. Also, categories within a given tree differ ontologically from any other category on another tree. Also, each category was characterized by a set of ontological attributes (Slotta et al., 1995). For example, in Figure 2.2, the ontological attribute hungry can be applied to the category of animals, which is a sub-category of "living", which has subcategories, such as human. Therefore, animals and humans are not ontologically distinct (Chi & Slotta, 1993). They both share the same ontology. This means that two categories are ontologically distinct only if they occupy parallel (horizontally separate) branches of the tree.

When students assign a concept to a category, this concept takes over all the features of the new category (Chi et al., 1994). From this perspective, misconceptions can be seen as miscategorization of a concept. Chi and Roscoe (2002) defined misconceptions as "the concepts categorized into an ontologically inappropriate category" (p.4). Whether miscategorization occurs in lateral categories or hierarchical categories is crucial in understanding Chi's theory. He defined the hierarchical theory with an example (Chi & Roscoe, 2002), which is illustrated in Figure 2.3. In this figure, a

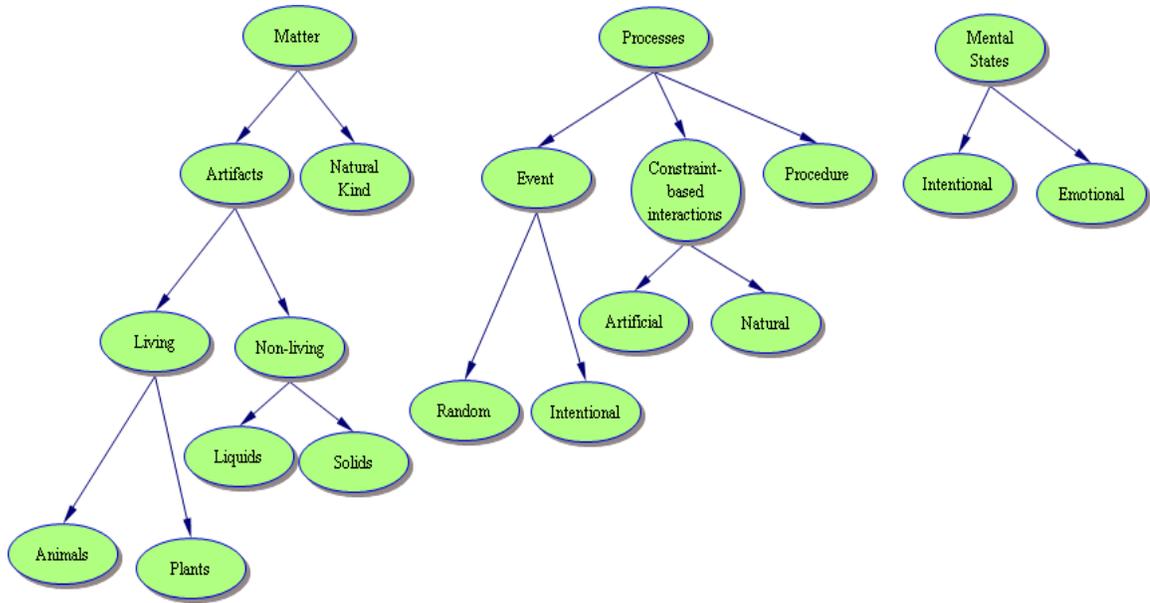


Figure 2.2 Ontological categories by Chi & Slotta, (1993, p.253).

cobra is a subordinate category of poisonous snakes, which is a subordinate of reptiles and reptiles are a subordinate of living things. These categories are hierarchically related. Chi wrote, “Miscategorization of a concept into a hierarchically-related category would not constitute a misconception” (p.13). Miscategorization of a concept into a hierarchically-related category is called preconception (Chi & Roscoe).

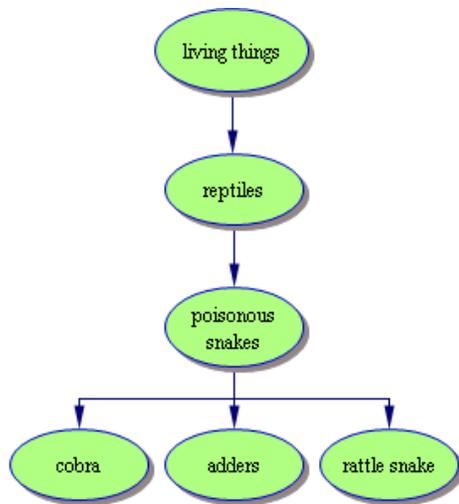


Figure 2.3: Hierarchical category of snakes (based on Chi & Roscoe, 2002).

Lateral categorization is distinct from hierarchical categorization. Lateral categories do not share any hierarchical relationships with each other. Some lateral categories share higher super-ordinate categories (Chi et al., 1994), such as cobra and stone. Both cobra and stone are subcategories of natural matter, but are ontologically distinct categories because they do not share the same ontological attributes. For example, being hungry cannot be applied to a stone, while it can be applied to a snake. After clarifying the lateral and hierarchical categorization, misconception can be understood more clearly. Misconception is, again, miscategorization of a concept into an ontologically distinct category, which means into a distinct lateral category.

Conceptual change is explained as correcting the misconceptions in this model. Thus, ontological distinction underlies Chi's conceptual change theory "Conceptual

change occurs when a concept has to be re-assigned to an ontological distinction category (across trees)” (Chi et al., 1994, p.31). This concept, which will be reassigned, has initially been placed into a wrong category. An important question exists, however, as to whether all re-assignments of concepts count as conceptual change. Chi et al. stated that conceptual change occurs only across trees, which means that concepts shifted laterally can be categorized as conceptual change (Chi et al.). If the shift is within hierarchical categories, it is categorized as conceptual reorganization. Conceptual reorganization occurs in hierarchically related categories. Thus, misconceptions cannot be reorganized because they are located in lateral categories. However, preconceptions can be reorganized because they are in the same hierarchical categories.

Why is conceptual change difficult? Chi et al. (1994) express the view that conceptual change is difficult when students are not aware of their misunderstanding, or they lack an alternative category into which they can shift the concept (Chi & Roscoe, 2002). Chi et al. could not provide an answer for the second obstacle, where students lack alternative categories. They recommend a few strategies, such as teaching the missing category directly, teaching the characteristics of the missing category, or providing hands-on demonstrations or simulation activities (Chi & Roscoe). Chi did not talk about how to make students aware of their misconceptions.

Chi’s conceptual change model is different from other models that focus on intuitive knowledge, such as diSessa (1993). Chi agrees with diSessa’s assertion that intuitive knowledge comes from everyday experiences and that it is primitive, but does not agree that intuitive knowledge does not have any coherence (Chi & Slotta, 1993). His

theory of ontological categorizations provides a certain level of coherence to intuitive knowledge. Another point of disagreement between Chi and diSessa revolves around misconceptions. diSessa indicated that misconceptions were derived from intuitive knowledge and cannot be confronted or overcome. Chi demonstrated that misconceptions could be repaired by reassigning them into appropriate categories.

### *Branch Jumping and Tree Switching*

Thagard (1991) started an investigation of conceptual change by defining concepts. Thagard defined concepts as “complex structures akin to frames, but which (1) give special priority to the kind and part-whole relations that establish hierarchies, and (2) express factual information in rules that can be more complex than simple slots”

(p.112). According to Thagard, concepts are (p.112):

- A kind of:
- Sub-kinds:
- A part of:
- Parts:
- Synonyms:
- Antonyms:
- Rules:
- Instances:

This definition of concepts shows that conceptual change is effected by adding or deleting parts and by reorganizing ideas throughout the concept formation. In addition, this definition shows that concepts are a part of a complex system. Thagard lists different kinds of conceptual changes in terms of degree of increasing severity:

- 1-Adding a new instance
- 2-Adding a new weak rule

- 3-Adding a new strong rule
- 4-Adding new part-whole relations
- 5-Adding new kinds of relations
- 6-Adding a new concept
- 7-Reorganizing hierarchies by branch jumping
- 8-Tree switching

Among these eight conceptual changes, the first three can be interpreted as belief revision, which is similar to assimilation. There is no change in the first part, besides adding new instances and assimilating them. However, toward the latter part of the list, especially branch jumping and tree switching, these changes are similar to accommodation. Thagard (1991) defined the last two as “changes that are very difficult to make on a piecemeal basis” (p.115). Thagard sees tree switching or branch jumping as more radical and revolutionary than the evolutionary change made up of piecemeal belief revision, such as adding a new instance or a weak rule.

Although Thagard’s model appears to be similar to the ontological categorization model of Chi and Slotta (1993), it is different in that Thagard’s definition of concepts looks like he categorized the entities or events according to their similar characteristics, while Chi and Slotta’s definition looks like the classification of concepts based on ontological characteristics of the concepts. Also, Chi and Slotta identify three ontological categories: matter, process, and mental state. All entities belong to one of these three categories. For example, Chi et al. (1994) thought that animals and humans are not ontologically distinct, meaning that they share the same characteristic. However, Thagard

(1992) put animals and humans into different categories, and also placed the human both as a separate category and a category under the animals.

### *Portfolio Culture*

The study by Duschl and Gitomer (1991) was unique in terms of using assessment to foster conceptual change. Portfolio culture was described as a model of educational practice to facilitate conceptual change. Duit (1999) characterizes portfolio culture as a holistic constructivist approach to conceptual change. This theory provides opportunities for both teachers and students to face and develop their scientific understanding. In addition, students are equipped to take responsibility for their own restructuring (Duschl & Gitomer).

Two distinguishing characteristics of portfolio culture (Duschl & Gitomer, 1991) are “assessment-based interactions that teachers have with students to monitor meaningful learning” and “the project orientation of instructional activities and instructional tasks” (p.848). Assessment is the main focus in this theory because it provides some advantages to both teachers and students. For example, students’ prior knowledge can be identified, and conceptual development – not the outcome – can be elucidated by appropriate assessment methods (Duschl & Gitomer). Students’ scientific knowledge was assessed through the use of portfolios, which are collections of the students’ work that originate from instructional activities, and that include evidence of the process of students’ conceptual development. Instructional processes start with a problem statement and portfolios are developed for this problem statement.

Portfolio science culture and traditional science culture were compared by Duschl and Gitomer (1991) in Table 2.1. Careful analysis of the role of learners in portfolio culture shows that the metacognitive approach was applied in this method.

Traditional science culture	Portfolio science culture
View of science	
Strict hypothetical-deductive scientific method	Partial scientific method
Logical positivist epistemology	Scientific realism/semantic conception epistemology
Observation/theoretical distinction tenable	Observation/theoretical distinction untenable
Role of learner	
Low student input/non-active image	High student input/active image
Scientific meaning received	Scientific meanings negotiated
Low level of reflection	High level of reflection
Use student development strategies	Uses strategies/principled knowledge
Role of teacher	
Disseminator of scientific knowledge	Crafter of scientific knowledge
Non-participant in construction of scientific knowledge	Participant in construction of knowledge about science
Strict adherence to prescribed curriculum	Modify and adapt prescribed curriculum
Curriculum goals	
Scientific knowledge	Knowledge about science
What we know	How and why we know
Emphasize fully developed final form explanations	Emphasize knowledge growth and explanation development
Breadth of knowledge	Depth of knowledge
Basic scientific knowledge	Contextualized scientific knowledge
Curriculum units discrete	Curriculum units connected

Table 2.1: Contrasting traditional and portfolio cultures in science classrooms (Duschl & Gitomer, 1991, p.849)

Some characteristics of portfolio culture, such as negotiation of scientific meanings and high level of reflection, were observed in Beeth's (1998b) and Georghiades's (2000) studies. Also, teachers' roles in portfolio culture show some similarities with metacognitive instruction. Portfolio culture has the potential to be an effective instructional strategy to teach conceptual change, provided that it is explained in more detail and tested by the researcher in the classrooms.

### *Socio-cultural Perspective*

Conceptual change in sociocultural perspective is explained in detail by Ivarsson, Schoultz, and Saljo (2002). Language is the most important tool in the sociocultural perspective. Everything, including the language, is considered a tool in this perspective. Socio-cultural perspective looks at the conceptual change process as using the appropriate tool in a specific situation (Ivarsson et al.). Two types of tools are used in conceptual change according to Ivarsson: intellectual tools (concepts), such as the concept of gravity and force, and physical tools (artifacts), such as maps and globes. In this sense, almost everything around us is considered as a tool (Ivarsson et al.).

Conceptual change in the sociocultural perspective “involves development of tools using practices” (Mayer, 2002). Learning occurs in a social context with interactions between members of society. People reason with artifacts and the tools serve as aids to understanding the world in a sociocultural perspective. Ivarsson et al. (2002) presented a study investigating how children reason when using a culturally meaningful tool, which is a two-dimensional map. Interviews were conducted with a focus upon the

shape of the Earth and the characteristics of gravity. Data were collected at a school with 18 children, ages seven through nine. Ivarsson et al. discovered that students obtained a good understanding of the shape of the Earth and the nature of gravity, as opposed to previous studies conducted by Vosniadou and Brewer (1992). Ivarsson et al. claimed that using culturally meaningful tools allow students to understand the concept. If children are interviewed without any meaningful artifacts, they express views which are totally different from those who are interviewed with artifacts. Another similar study (Schoultz, Saljo, & Wyndhamn, 2001) produced similar results. The only difference between Schoultz et al. and other studies was that Schoultz et al. used a three-dimensional model of the globe.

It is not surprising that using two- or three-dimensional artifacts yields totally different results than not using artifacts. This is especially true when an artifact is used which is a part of the question, in that it may help in some way to provide the participants with the answer. Because the artifacts might help the students to recall an answer that they saw in a textbook or elsewhere, the reliability of the findings of those studies are questionable.

### *Knowledge Restructuring*

Knowledge acquisition was the starting point of Carey's (1988) studies. She believed that the novice-expert shift is the most appropriate way to explain knowledge acquisition. Organization of knowledge by a novice is different than organization by the expert, in the sense that the novice focuses on more basic and superficial structures while

the expert focuses on the laws (Carey). The shift from novice to expert is defined (Wiser & Carey, 1983) as a “shift from one system of beliefs about the physical world to another, one set of concepts to another, one set of problem-solving capabilities to another...this shift resembles theory change in the history of science” (p.267). Carey proposed that the novice-expert shift involves “restructuring of the knowledge as well as accumulation of new facts, new production roles, and so on” (p.5). Thus, shifting from novice to expert is a gradual process that includes collecting the information and building meaningful connections among them as the experts do. Both novices and experts share same concepts but the difference between them is that they attach different properties to the concepts and relate them differently to others.

Two types of restructuring were suggested by Carey (1988): weak restructuring and strong restructuring. Weak restructuring occurs when the novices have more experience and build relationships among the concepts which they already possess. Thus, novices change their problem-solving strategies for the old problems and develop new strategies for the new problems (Carey). Carey offers the process of becoming an expert in chess as an example of weak restructuring. All the moves, rules, and goals are shared by both novices and experts. By gaining experience, the novice restructures his knowledge and produces new strategies to win.

Strong restructuring is more radical than weak restructuring. Strong restructuring includes all the changes weak restructuring does, plus changes at the core of the concept (Carey, 1988). Strong restructuring happens in more extreme examples than becoming an expert in chess, such as transitioning from Newton mechanics to Quantum mechanics,

and is similar to a paradigm shift (Carey). In the history of science theories emerge through strong restructuring.

This restructuring theory is different from the initial conceptual change model in a couple of different ways. The first difference is that the individual retains the old concept after the conceptual change. The concept does not change, but the organizations and interactions among other concepts do. Another difference is that misconceptions are not considered in Carey's (1988) model. They are considered to be uncorrected connections between concepts, which are corrected by adding cumulatively new knowledge and making new connections with other concepts. The last difference is that accumulation of the knowledge plays a major role in knowledge gain, so both strong and weak restructuring are ongoing processes.

#### *Anomalous Data and Theory Change*

Misconception research showed that pre-instructional beliefs about the natural world sometimes conflict with scientific theories taught in school (Driver, 1989; Vosniadou & Brewer, 1992). Students resist changing their pre-instructional beliefs even though these beliefs contradict the new data. These new data, which contradict pre-existing data, are called anomalous data. Anomalous data have been used in science instruction (Hewson & Hewson, 1984; Nussbaum & Novick, 1982) to create dissatisfaction with students' current theory to encourage them to adopt the scientific data which does not contradict the new data. Anomalous data do not always foster conceptual

change. However, in some instances it blocks students' understanding (Chinn & Brewer, 1993).

Chinn's conceptual-change theory is based on the understanding of how students respond to data that contradicts pre-instructional theories (Chinn & Brewer, 1993). To understand the nature of anomalous data, it is necessary to outline the use of anomalous data in instruction. Chinn and Brewer proposed seven types of possible responses of an individual to anomalous data.

1-Ignore the data: students or scientists basically ignore the data. Thus, the data does not need to be explained at all (Chinn & Brewer, 1993). Since the data is ignored, there is no need to change the theory.

2-Reject the data: This is similar to ignoring the data, but an explanation is given as to why the data were rejected (Chinn & Brewer, 1993). Again, the theory does not change at all.

3-Exclude the data from the domain of theory: A learner can announce that data does not belong to this domain of theory (Chinn & Brewer, 1993). Data again does not have to be explained. The theory does not change.

4-Hold the data in abeyance: Anomalous data can be temporarily inactivated, with the learner promising to deal with it later. Even though the initial theory A does not change, learner assumes that theory A will be articulated in order to explain the data (Chinn & Brewer, 1993).

5-Reinterpret the data while retaining theory A: Anomalous data is accepted, provided that it is reinterpreted to fit the theory (Chinn & Brewer, 1993). Theory does not change, but data changes as a result of its reinterpretation.

6-Reinterpret the data and make peripheral changes and change of theory A: The individual makes some minor changes in the theory so that anomalous data can be explained (Chinn & Brewer, 1993). These kinds of changes were observed by Vosniadou and Brewer (1992). Students who had the flat-Earth model changed their model when they were introduced to the spherical model of Earth. They changed their flat-Earth model into disk-like Earth or hollow Earth. This kind of change seems similar to weak restructuring (Carey, 1988).

7-Accept the data and change theory A, possibly in favor of theory B: Contradictory data is explained with a new theory because the old one was not capable of explaining anomalous data. This kind of change occurs by throwing away theory A in favor of theory B or by changing the core beliefs of theory A. Table 2.2 shows the seven forms of responses to the anomalous data. Chinn and Brewer (1993) state that these seven responses are common to both scientists and students. As it can be seen from Table 2.2, the theory does not change in the first six responses, or the “theory-preserving responses” (p.14), but does change in the last response.

Type of response	Features of the response		
	Does the individual accept the change?	Does the individual explain the data?	Does the individual change theories?
Ignoring	No	No	No
Rejecting	No	Yes	No
Excluding	Yes or maybe	No	No
Abeyance	Yes	Not yet	No
Reinterpreting	Yes	Yes	No
Peripheral change	Yes	Yes	Yes, partly
Theory change	Yes	Yes	Yes

Table 2.2: Features of seven responses to anomalous data (Chinn & Brewer, 1993, p.13)

Chinn and Brewer (1993) proposed three fundamental dimensions for attempts to coordinate the theory and the data: “(a) whether the individual accepts the data as valid, (b) whether the individual can provide an explanation for why the data are accepted or not accepted, and (c) whether the individual changes his or her prior theory” (p.13). The first two dimensions seem to be similar to the condition of accommodation (Posner et al., 1982), and the last dimension seems to be similar to dissatisfaction.

When teachers are using anomalous data to change a theory, some factors influence how students respond to such data (Chinn & Brewer, 1993). Those factors identified by Chinn and Brewer were “characteristics of individual’s prior knowledge, characteristics of the new theory, characteristics of the anomalous data, and the processing strategies” (p. 5). Those factors play a role in all kinds of classroom

environments. But the question arises as to how a lesson can be designed, which pays special attention to all these factors when introducing anomalous data.

Introducing the anomalous data is a challenge in science education because it might result in unexpected outcomes (Chinn & Brewer, 1993). Especially in the case of theory change, which is a rational and reflective process that requires some strategies. Chinn and Brewer introduced some instructional strategies for promoting theory change. Those strategies are presented in Table 2.3.

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Influencing prior knowledge
1. Reduce the entrenchment of the student's prior knowledge
2. Help students construct appropriate ontological categories
3. Foster appropriate epistemological commitments
4. Help students construct needed background knowledge
Introducing the alternative theory
1. Introduce a plausible alternative theory
2. Make sure that the alternative theory is of high quality
3. Make sure that the alternative theory is intelligible
Introducing anomalous data
1. Make the anomalous data credible
2. Avoid ambiguous data
3. Use multiple lines of data when necessary
Influencing processing strategies
1. Encourage deep processing

---

Table 2.3: Instructional strategies for promoting reflective theory change (Chinn & Brewer, 1993, p.31)

Introducing the alternative theory in the instructional strategies does not seem too different from Posner et al.'s (1982) conditions. For example, alternative theories should be intelligible, plausible, and high quality (fruitful), which are also characteristics of the newly introduced concepts in Posner's theory. Thus, it can be assumed that theory change is the same as concept change.

One of the shortcomings of this theory is that it does not talk about the misconceptions directly, but it seems that students' initial theories are considered misconceptions because they contradict the anomalous data. If students do not change the theory to explain anomalous data, it can be assumed that they keep the alternative conceptions; and if they tend to change the theory, it can be assumed that they give up the old theory and develop a new one.

In conclusion, anomalous data causes conceptual change at different levels in Chinn and Brewer's (1993) conceptual change model. When students try to change their theory to explain the anomalous data, they face a radical conceptual change. It is similar to Kuhn's (1970) proposal for how science progresses. When anomalies arise, scientists start to consider shifting the paradigm in order to explain the new data. Vosniadou (1994) and Chi et al. (1994) have different approaches to conceptual change. Vosniadou and Chi et al. focused on the process of how conceptual change occurs. They proposed models to explain the process, but they did not tell what causes conceptual change in the first place. Vosniadou's approach is similar to Chinn's approach in terms of the change that occurs when scientific data conflicts with students' theories (intuitive model conflicting with scientific model). On the other hand, there is not a connection to Chi et al.'s conceptual

change model, because Chi et al. views conceptual change as concepts shifting from one ontological category to another.

### *Cognitive Psychology Perspectives*

The review of the literature shows that there is a significant gap between science education research and cognitive psychology in terms of the perspectives on the conceptual change models. Both groups have focused upon different aspects of the conceptual change process. For example, researchers in cognitive psychology have focused upon how knowledge is developed and how conceptual change occurs, while science educators have focused upon specific instructional strategies to promote conceptual change. Conceptual change models from the science education perspective, (Hewson & Thorley, 1989; Posner et al., 1982), are presented in the previous section. The following sections will focus upon the cognitive psychology perspectives, and specifically Vosniadou's conceptual change model, which shaped the theoretical framework of the current study.

#### *Vosniadou: Conceptual Change as Modification of Mental Models*

Vosniadou began her research by following Carey's (1988) conceptual change model. In that model, new structures were created by either reinterpreting the old information or accounting for new information in a more organized and coherent structure (Carey). Based on this restructuring model, Vosniadou developed the conceptual change model which was enlightened by mental model development.

Students construct intuitive knowledge through everyday experiences (Vosniadou & Brewer, 1987). Some researchers think that intuitive knowledge is fragmented and nonsystematic (diSessa, 1988) so that students do not have a coherent model to explain their everyday experiences. On the other hand, Vosniadou (1991) believes that students' intuitive knowledge is not fragmented and students can construct coherent mental models. Vosniadou wrote that "students try to synthesize the information they received from adults and from their everyday experience into coherent mental models which they then try to use in a consistent fashion" (p.225). A mental model is defined as a dynamic structure that is "created on the spot for the purpose of answering questions, solving problems, or dealing with other situations" (Vosniadou & Brewer, 1992). Major characteristics of mental models are that they can be manipulated mentally, they are created by the individual on demand, they can be scientific or nonscientific, and they are reconstructed when new information is added (Vosniadou & Brewer, 1994). Three kinds of mental models have been proposed: intuitive, synthetic, and scientific (Vosniadou).

Intuitive models are the models that students develop through everyday experiences and are not influenced by adult scientific models (Vosniadou, 1991). These models are usually based on the observations of the physical world. Some examples of this kind of model are the model of the flat-Earth (Vosniadou & Brewer, 1992) and the model of the day/night cycle, in which night comes when the sun hides behind the mountains (Vosniadou & Brewer, 1994).

The second type of model is the synthetic model, which is similar to misconceptions (Vosniadou, 1991). Students develop synthetic models when a scientific

explanation is provided to them (Vosniadou & Brewer, 1992, 1994). Synthetic models are not intentionally developed. They are developed when learners' prior knowledge conflicts with school science. For example, students' observations usually lead them to believe that the Earth is flat. When they are told that the Earth is a sphere, the new information "sphere Earth" conflicts with what they believe or what they observe. Therefore, they develop synthetic models of the Earth, which are "hollow Earth," "flattened sphere," "dual Earth," or "disk Earth" (Vosniadou & Brewer, 1992).

Scientific models, which are also called consensus models, are the models held usually by adults in the society and coincide with current scientific views (Vosniadou, 1991). Scientific models are called consensus models because at first scientists have their own mental models, but at some point they all agree on the one best model that can produce a solution to a problem in a specific domain.

Vosniadou (1994) rejected the traditional conceptual change approach, which was based on the replacement of one theory with another. She believed that conceptual change is a product of "the gradual lifting of constraints, as presuppositions, beliefs, and mental models added, eliminated, suspended, or revised during the knowledge acquisition process" (p.125). Conceptual change in Vosniadou's theory occurs in two different ways: enrichment and revision. That is, conceptual change proceeds "through the gradual modification of one's mental models of the physical world, achieved either through enrichment or revision" (Vosniadou, p.46).

Enrichment was defined as the addition of information into an existing conceptual ecology (Vosniadou, 1994). It appears that enrichment seems to be similar to assimilation

(Posner et al., 1982). Both enrichment and assimilation were described in the same way which is the integration of a new concept into an existing structure without any conflict between the new and old conceptual structures. Both enrichment and assimilation were also perceived as the easiest types of conceptual change processes which can occur by simply being exposed to information presented in the classroom.

As opposed to enrichment, revision is a more radical process in conceptual change. Revision involves the changes in the structure of theory (Vosniadou, 1994). Like the similarities between the enrichment and assimilations, revision seems to be similar to accommodation which occurs when the new information is inconsistent with the existing beliefs. According to Vosniadou and Ioannides (1998), enrichment is much easier than revision because revision is a more complex process than enrichment.

Entrenched presuppositions or constraints are organized in a framework theory which is not available to conscious awareness and hypothesis testing (Vosniadou & Brewer, 1994). Presuppositions are the fundamental ingredients of intuitive knowledge (Vosniadou, 1991). Vosniadou believed that presuppositions might be innately or empirically learned from early infancy and guide the way children interpret the observations and the information they received from the culture to construct knowledge (Vosniadou & Brewer, 1994). Some of the presuppositions students have in their mental models of Earth were “the ground is flat,” “an unsupported things fall,” (Vosniadou & Brewer, 1992), and “Earth is a physical object rather than an astronomical object” (Vosniadou & Brewer, 1994). Two types of presuppositions, ontological and epistemological, compose the framework theory, which is the conceptual system that

children form to interpret the observations about the physical world, as well as their interpretations of the information provided by adults (Vosniadou & Brewer, 1994). The framework theory can both facilitate the knowledge acquisition process and hinder later learning because children's everyday experiences often differ from scientific explanations (Vosniadou, 1999). In addition to the framework theory, it was assumed that children construct specific theories to explain phenomena.

Specific theories consist of beliefs that give rise to mental models under the constraints of the presuppositions of the framework theory (Vosniadou & Ioannides, 1998). Also, Vosniadou and Brewer (1992) distinguished the difference between beliefs and presuppositions. Beliefs are based on everyday observation and are easy to change. However, presuppositions are based on constraints, and it is difficult to change them.

Vosniadou's model has been criticized by several researchers (Ivarsson, J., Schoultz, J., & Saljo, R., 2002; Schoultz, J., Saljo, R., & Wyndhamn, J., 2001) in terms of the methodology used in her studies. Ivarsson et al. and Schoultz et al. claimed that the subjects in Vosniadou's studies made use of the drawings as the question resources for their reasoning. Ivarsson et al. and Schoultz et al. did not acknowledge the fact that every study that utilizes any kind of artifacts, which could be any type of physical or mental representation of related content, could possibly have some kind of instructional value. Ivarsson et al. and Schoultz et al. also critiqued Vosniadou because the "interviewer is the dominant communicative partner, who controls the floor and who makes powerful communication moves" (Schoultz et al.). Thus, when the interviewer repeats the students' answers, the student thinks that the interviewer wants another answer. This is a

methodological issue that some researchers believed had a negative effect on the reliability of the interview process. However, considering the age group studied, it seems that Vosniadou needed some kind of member checking as apart of the study. Repeating the answer might have been the only way in the study to get student confirmation or disconfirmation of whether the interviewer heard what the interviewee said.

Vosniadou was also critiqued because she underestimated children's knowledge of astronomy, based upon the method she applied (Schoultz, J., Saljo, R., & Wyndhamn, J., 2001). Schoultz et al. used three-dimensional models in a study to investigate children's understandings of the Earth within a socio-cultural perspective. They discovered that when participants had access to a three-dimensional globe, they could understand gravitation better and explain why people live all around the Earth without falling off of it. Schoultz et al. concluded that Vosniadou underestimated children's knowledge because she did not use a physical tool in her study through which students could have expressed themselves.

### *Historical Development of the Model*

Throughout her career, Vosniadou made some changes in her conceptual change model and these changes can be observed in her earlier works. Vosniadou adopted Carey's (1988) work as a theoretical frame when she first developed her model. She constructed a model around the notion that conceptual change is restructuring knowledge (Vosniadou & Brewer, 1987). She focused on two types of restructuring, radical and weak. In her later works (Vosniadou & Brewer, 1992, 1994), she abandoned Carey's

model and developed her own. The idea of radical restructuring did not fit into her model because her model was based on the notion that children's naïve knowledge shows a coherent structure. This means that children already possess a consistent model from which they can reason. Vosniadou did not believe that conceptual change is replacement of the old concept with a new one. Thus, she gave up the idea of radical restructuring and focused on modifying the mental model through enrichment and revision for the conceptual change, because radical restructuring involves a fundamental change in knowledge structure.

### *Learning*

According to Vosniadou, learning in school requires students to complete the skills such as making observations, memorizing, understanding, predicting, analyzing the data, interpreting, and applying the new knowledge in other situations. These skills could not be developed without students' active involvement in their learning (Vosniadou, 2001a). The current study specifically followed two of the Vosniadou's learning perspectives. The first one is that learners construct their own knowledge. That view was presented by Vosniadou; "students should be encourage to construct their own knowledge and skills through active processing, rather than being passive listeners" (p.382). The second one is that application to real-life situations is important for meaningful learning. That view also was presented by Vosniadou; "when learning is situated in real-world context, what is learned is better remembered" (p.382). Both suggestions reflect the findings of research studies from science education and from the

cognitive psychology perspectives over the last few decades. Therefore, the instructional intervention applied in this study was selected and implemented with these suggestions in mind.

In general the conceptual change model suggested by Vosniadou includes the following perspectives. These perspectives on conceptual change guided the current study.

1. Conceptual change is a process of modification of mental models through enrichment and revision.
2. Conceptual change is a slow and gradual process, where new information from instruction is added to an initial explanation, which can evolve and reorganize into a scientific model.
3. Learners' prior knowledge can be both an obstacle to, and a vehicle for, conceptual change.
4. Learners play an active role in constructing their mental models.
5. Learners have a coherent explanation for events which can be influenced by their cultural backgrounds and sensory experiences.

#### Literature Review on Tides

The tides are represented in introductory astronomy, physics, and oceanography textbooks to varying extents. Some books allocate a whole chapter to the tides, while others allocate a few pages to tides in the chapters related to the moon (Galili & Lehavi, 2003). Like all other content, there is not a single strategy in textbook representations of

tides. Textbooks focus on different models of the tides when explaining the causes and effects. The biggest difference in the presentation of information on the tides is between introductory astronomy textbooks and oceanography textbooks.

### *Presentation of Ocean Tides in Introductory Astronomy Texts*

Introductory astronomy textbooks usually focus on the explanation of what causes the tides from a physics perspective. These textbooks usually apply the equilibrium theory of the tides when generating their explanations. The equilibrium theory of the tides assumes that an ideal ocean of uniform depth covers the Earth. All other effects, such as friction between water and the ocean floor, and the topography of the ocean floor (Duxbury & Duxbury, 1994) are ignored in the equilibrium theory. With this model of a uniform Earth, astronomy textbooks generate a theoretical explanation for tide-causing forces without considering the actual data observed on the Earth. Equilibrium theory can explain that a) two high tides occur every day, b) the time between two successive high or low tides is 12.50 hours, c) new and full moon phases generate the largest variation in sea level, d) quarter moon phases generate the smallest variation in sea level, and e) synchronous rotation produces tides. Synchronous rotation means that the moon always keeps the same face toward the Earth.

Besides in the astronomy texts, tides are also presented in some physics textbooks with an emphasis on equilibrium theory. Galili and Lehavi (2003) investigated 25 textbooks used for introductory physics courses in universities and colleges. They found that tides are rarely mentioned in the textbooks. Fourteen out of 25 textbooks mentioned

tides, and five out of 14 presented tides as an end-of-chapter exercise. Only five of the 14 textbooks provided a “sufficient explanation” for the tides. The meaning of “sufficient explanation” was not explained in the study.

*Presentation of Ocean Tides in Introductory Oceanography Texts*

Prediction of tides at a certain place on the Earth, by equilibrium theory, generally does not agree with observations at that location. The equilibrium theory is good for explaining the two-tidal bulge model but it cannot explain the actual tidal variations at different places on the Earth. As a result, the equilibrium model cannot be used to make accurate predictions of the tides at a specific location. Variations of tides can be better understood using the dynamic theory of tides, which includes the effects of changes in ocean depth, the existence of continents, and friction between the ocean water and ocean floor (Duxbury & Duxbury, 1994; Knauss, 1978; Pond & Pickard, 1983; Team, 1989; Thurman, 1993).

The dynamic model seems to provide explanations for the questions that equilibrium theory cannot answer. The dynamic model is based on data derived from observation and from consideration of effects other than gravitational and centrifugal forces. Tidal variations at specific locations can be explained with the dynamic model because it considers geographic factors. On the other hand, astronomical perspectives provide the underlying reason of tide-causing forces, which is not made clear in the oceanography approach. It cannot be said that one method is better than the other; both have their advantages and disadvantages in terms of teaching and learning about tides.

The equilibrium model is a hypothetical model which makes it easier to explain the tides at an introductory level while the dynamic model considers all geological and physical factors which play a role in generating tides. Some of the major differences between oceanography and astronomy text presentations of tides are presented in the Table 2.4.

<i>Oceanography texts</i>	<i>Astronomy texts</i>
*Apply both equilibrium theory and dynamic theory, but emphasis is on dynamic theory.	*Apply only equilibrium theory.
*Ocean depth varies. Continents exist.	*Uniform ocean with same depth everywhere and no continents.
*Based on observations (predictions fit the observation).	*Based on theoretical assumptions (predictions do not fit the observations).
*Explains the types of tides: diurnal, semidiurnal, and mixed.	*Does not explain types of tides (only semidiurnal tides were presented).
*Explains the effects of ocean depth, continent, rate of rotation of the Earth, and Coriolis force on the tides.	*Does not explain any of the effects explained by the oceanography texts.

Table 2.4: Differences between oceanography and astronomy texts and their approaches

### *Tides in Science Education Literature*

The review of the science education literature revealed that there were not many studies that focused on students' understandings of the tides. In the science education domain a few researchers investigated students' understandings of tides (Bisard, Arons,

Francek, & Nelson, 1994; Galili & Lehavi, 2003; Skamp, 1994; Viiri, 2000a, 2004).

Among these researchers, Viiri (2004) developed a research-based teaching unit on the tides, while the other studies mostly reported the alternative conceptions of different astronomy concepts including the tides. Viiri (2000a) realized that students have difficulties understanding the high tide on the side of Earth that faces away from the moon. He conducted a study with 28 secondary school students, 61 primary school teacher trainees, and 41 secondary school teacher trainees. The purpose of the study was to discover what students can remember from the teaching and textbooks. Secondary school students studied the most rudimentary ideas of tides at the primary level. Both groups of preservice teachers had studied the tides at a higher level than secondary school. The data was collected through a questionnaire, which included both open and structured multiple-choice tests. Some questions included drawings. Although Viiri's study did not aim to reveal misconceptions, his findings can give us some clues about the misconceptions students might have. Viiri categorized students' answers into four groups, presented in Table 2.5. Viiri discovered that, in general, students' understandings were very poor; none of the secondary school students mentioned the two bulges, all of the groups favored the moon's attraction, and 25 % of the secondary school students mentioned factors such as wind, rain, and atmospheric pressure as the causes of the tides.

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A. Two-tidal bulges	A1. Two-tidal bulges and gradient of the moon's attraction A2. Two-tidal bulges and two forces (moon's attraction, centrifugal force) A3. Two-tidal bulges and the moon's attraction
B. One-tidal bulge	B4. One-tidal bulge and the moon's attraction B5. One-tidal bulge and movements of the moon and the sun
C. Tides at the coast	C6. Tides at the coast and the moon's gravitation C7. Tides at the coast and the Earth's rotation C8. Tides at the coast and the movements of the Earth, the moon, or the sun C9. Tides at the coast and wind, rain, etc. C10. Tides at the coast with no explanation
D. No pictures	D11. Moon's gravitation D12. Earth's rotation D13. Movements of Earth, the moon or the sun D14. Wind, rain, etc. D15. No explanation

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Table 2.5: Categories of students' ideas (Viiri, 2000a, p.107)

Referring to Table 2.5, section A contains students answers that included a two-tidal bulge model, but with different explanations. Sections B and C contain some misconceptions, such as a one-tidal bulge model; considering tides only as a coastal phenomenon; explaining tides as the effects of rotation of the moon, Earth, and the sun; and explaining the tides as the effects of wind and rain. These misconceptions reflect both astronomy and oceanography perspectives. The misconception of a single tidal

bulge model seems to reflect an astronomical perspective because students used the moon's attraction for the explanation. Other misconceptions seem to reflect an oceanography perspective because those surveyed mentioned tides at coasts and the effects of wind, rain, or atmospheric events. In general, misconceptions were both rooted in astronomical and oceanography perspectives. Viiri (2000a) recommended that both teachers and textbook writers use the gradient of the moon's attraction in explaining tides.

Viiri (2004) developed a research-based unit on tides for lower secondary school students. The unit was based upon the "scientific theory of tides, textbook, and also analysis of students' conceptions" (p.463). The unit required a total of 50 minutes teaching time, plus 15 minutes for the pre-test and 15 minutes for the post-test. He described the unit as not being student-centered "because the description and explanation of tides needs rather abstract ideas and combines many laws and quantities, the unit was not very student-centered" (p.475). The unit strictly reflected the astronomy perspective of tides instruction where no connections were made to the dynamic model of tides. The unit was tested with two 8<sup>th</sup> grade classrooms, one in 1999 (n=10) and one in 2000 (n=17). Students' understandings of tides were assessed with an open-ended questionnaire, and with drawings and explanations before and after the instruction. In the first year group, 3 out of the 10 middle school students had a scientific understanding of tides before the instruction. After completing the research-based unit, all students in the first year group held the two-tidal bulge model and 9 of the 10 participants held a scientific understanding of tides. In the second year group, none of the 17 participants

held scientific understanding of tides before the instruction. After the instruction, 12 of 17 middle school students held two-tidal bulge model with a scientific understanding, 4 of 17 held the two-tidal bulge model with different explanations, and 1 of 17 held a one-tidal bulge model. That study showed that with appropriate instruction, scientific understanding of tides appeared to be promoted within middle school students.

The instruction applied by Viiri (2004) is compared to that used in the current study. The main differences between these two studies are presented in Table 2.6. Three major areas are important in this comparison. The first one is that the instruction times were not the same for both studies. The instruction applied in the current study took more than three times longer than Viiri's instruction. The main reason for the longer instruction time difference came from the use of different approaches in the tides instruction. The current study applied an oceanography approach which required collecting and analyzing data while Viiri's instruction applied an astronomy approach which did not require collecting and analyzing the data. The second difference between the instruction in the two studies came from the topics included. While the instruction in the current study only covered the main points of both models in tides instruction, Viiri covered a wide range of topics from physics and astronomy. The current study focused on only the main components of tides and they were taught in three class periods. The third major difference was that the instructional methods were different in the two studies. The current study used an inquiry-based instruction, which paid specific attention to hands-on activities in which students had control of their learning. Viiri followed a more traditional

method and applied teacher-centered instruction. Most of the instruction in Viiri's study occurred as teacher-generated discussions and teacher presentations.

Viiri (2004)	Current Study
	<i>Instruction time</i>
50 min	180 minutes
	<i>Topics included</i>
-States of matter	-General law of gravitation
-Acceleration and force interaction	-Centrifugal forces
-General law of gravitation	-Two water bulges
-Graphical representation of gravitation law	-Tides twice a day/rotation of Earth
-Gradient of moon's interaction	-Comparison of moon's and sun's influence on tides
-Free fall	
-Two water bulges	
-Tides twice in a day	
-Comparison of moon's and sun's influence on tides	
-Tides in the moon of another planet	
	<i>Instructional methods</i>
-Mostly teacher-centered	-Mostly student-centered
-Teacher presentation	-Gathering and organizing data
-Teacher guided, authoritative discussion	-Generating graphs
-Teacher guided, dialogic discussion	-Analyzing graphs
-Peer discussion	-Correlating tides with moon phases
	-Peer discussion
	-Manipulating a computer simulation
	-Manipulating a psychomotor model

Table 2.6: Comparison of instruction in Viiri's (2004) and current study

In another study, Galili and Lehavi (2003) investigated the importance of weightlessness and tides in teaching gravitation. They examined 25 textbooks for introductory physics courses at universities and colleges and administered a survey to 75 high school physics teachers and 28 university students majoring in science. They discovered that textbooks rarely mention tides and the textbooks that did mention tides used them to illustrate Newton's law of gravity. Both students and teachers failed to adequately explain the tides in this study. Subjects in this study mentioned only the new moon as causing spring tides. They did not mention anything about the full moon. None of the subjects in this study considered the Earth's gravitational acceleration. Instead, they focused on the gravitational forces of the moon and sun. In general, students developed a one-tidal bulge model with the main focus on the gravitational attraction of the moon. General findings of Galili and Lehavi's study are summarized in Table 2.7.

A shortcoming of Galili and Lehavi's (2003) study was that they administered a questionnaire which included a total of four open-ended questions, and only one of the four were about the spring tide and neap tide. Participants were provided a graphic representation of the Earth, sun, and moon in the configuration for a third-quarter moon phase, and they were asked to answer a question about tides. Using only one question without any further investigation does not seem adequate to obtain a good description of students' and teachers' conceptions of tides.

<i>Physics textbooks</i>	<i>Teachers-students</i>
- rarely consider tidal effects and almost never on small-scale distances	- very often fail to explain tidal effects
- normally explain tides by the difference of gravitational forces on the extremes of the Earth	- in the explanation of spring tides normally sum gravitational forces from Sun and Moon acting on the Earth
- normally do not explain spring tides	- confuse spring and high tides
- in the explanation of tides, rarely consider gravitational accelerations of elementary masses with respect to their center of mass	- do not consider force gradient along the body of the free falling Earth or the gravitational accelerations of elementary masses with respect to their center of mass
- are often silent regarding the symmetry of tidal bulges	- miss the symmetry of the tidal bulges

Table 2.7: Explanation of tides from textbooks, teachers, and students (Galili & Lehavi, 2003, p.1131)

Similarly, Bisard et al. (1994) examined students' alternative conceptions about astronomy concepts with another multiple-choice questionnaire. Bisard et al. included a question related to the tides in a multiple-choice survey, which was administered to 708 students from middle school, high school, and university levels. They found that three quarters of all the students did not recognize that high tides occur on the opposite side of the Earth when the Earth, moon, and sun were all aligned. The most popular incorrect

response was that there was a one-tidal bulge on the side of the Earth facing the moon. Students in that study knew that gravity plays a role in generating tides, but they could not provide the reasons for tides on the opposite side of the Earth. Although this study supports other studies' findings, Bisard et al.'s study was fairly limited because the conclusion was based on the students' answers to just one multiple-choice question.

In another study to identify the misconceptions about astronomy concepts, Skamp (1994) administered a technique called "Sort-Card" (p.63), which involved providing a group of cards to students and asked them whether they were "agree/disagree/or do not know" concerning the statement written on the card. Participants were also asked to provide written reasons for their views. Statements on the cards were derived from the research on misconceptions. Eighty-one preservice primary teachers participated in this study. A wide range of misconceptions for different astronomy concepts including the tides were identified in the study. Skamp indicated that most of his findings were similar to the findings of other studies except the ones related to tides. Misconceptions related to tides determined by Skamp were;

- Tides are caused by the moon orbiting the Earth every 24 hours
- There is only one high and one low tide each day
- The elliptical orbit of the moon around the Earth causes the tides: when the moon is closer to the Earth it is high tide
- High tides occur when the moon is visible
- High tide occurs on the opposite side of the Earth to low tide (p.65).

Skamp's findings were similar to the misconceptions diagnosed previously by Viiri (2000a) and Galili and Lehavi (2003). However, his methodology, which asked participants to express their opinion based on a statement provided by researchers, seems to have been inadequate for determining misconceptions because these statements may

have led the participants or provided information for participants' further explanations. Therefore, this study does not provide reliable findings of preservice primary teachers' conceptions of tides and causes of tides.

The research studies on tides suggest that students develop misconceptions related to both the astronomical approach and oceanography approach. It appears that students' understandings of tides depends on the understanding of both the equilibrium and dynamic theories. The equilibrium theory would increase the students' understandings of tide generating forces. On the other hand, dynamic theory might increase students' understandings of how oceans respond to these forces at specific locations on the Earth.

In summary, the comprehensive review of research on the understanding of tides tells us that tides need to be investigated further in science classes within different instructional settings. Except for one study (Viiri, 2004), none of the previous studies on tides thoroughly studied students' learning in a specific instructional design. All of the research on tides reported that both students and teachers failed to explain tides and the causes of tides. In addition, the limitation of textbooks for tide instruction was identified in other studies. All these points suggest the need for a descriptive study of participants' understandings of tides before and after instruction. While traditional, printed media types of instruction were investigated thoroughly in previous studies, other types of instructional interventions were not (Galili & Lehavi, 2003; Skamp, 1994; Viiri, 2004). It seems that, with the increasing emphasis on inquiry-based instruction from the National Science Education Standards (NRC, 1996), the oceanography approach for tide instruction is a promising intervention because in the oceanography approach students

have more opportunity to conduct scientific inquiry and all science process skills could be applied to the learning process.

## Inquiry-based and Technology-enhanced Instruction

### *Inquiry*

The National Science Education Standards characterize scientific inquiry as a way to teach and learn science for all grade levels (NRC, 1996). By conducting inquiry, students have first-hand experiences with the event, data gathering, and analyzing the data in an authentic way (Edelson, 2001). According to Edelson, inquiry skills include “formulating the hypothesis, collecting and evaluating evidence, and defending conclusion based on evidence” (p.362). The skills listed by Edelson seem to characterize the process of constructing scientific knowledge by the learner. Songer, Lee, and Kam (2002) said that inquiry helps students to deepen their content understanding, develop problem-solving abilities, and gain ownership of knowledge.

Five essential features of classroom inquiry determined by the National Research Council (2000, p.25) are:

- Learner engages in scientifically oriented questions
- Learner gives priority to evidence in responding to questions
- Learner formulates explanations from evidence
- Learner connects explanations to scientific knowledge
- Learner communicates and justifies explanations

These five features resemble the way scientists conduct scientific inquiry. Therefore, scientific inquiry in science classes seems to be conducted in an authentic way similar to how scientists investigate phenomena. Etkina, Matilsky, and Lawrence (2003) suggest that students can learn the content and processes better by following the way that scientists investigate problems. The only difference between the scientists and the students is that while scientists inquire more independently, students' inquiry requires support and guidance from teachers (Lee & Songer, 2003).

There is no single way to conduct scientific inquiry across the science disciplines. The National Science Education Standards state that scientific inquiry can be done in many different ways across or within a discipline (NRC, 1996). Among those ways of inquiry, particularly authentic learning can be applied to promote scientific inquiry in science classrooms (Edelson, 2001; Etkina et al., 2003; Lee & Songer, 2003; Songer, 1996). Brown, Collins, and Duguid (1989, p.34) described authentic activities as the 'ordinary practices of the culture' where 'meanings and purposes are socially constructed through negotiations among present and past members'. Lecture-based instructional strategies usually do not challenge students to conduct activities in an authentic way where students need to plan and conduct investigations. According to Songer, the Internet and its resources hold promise for authenticity in science learning and teaching.

Conducting authentic activities is not always possible in science classrooms because of the limitations of the classroom environment (Lee & Songer, 2003). For example, collecting and analyzing data about fusion is not an easy task in K-12 science classes. However, within Web-based inquiry, students can access real-time data related to

this content and analyze the data with peers by mimicking scientists (Post-Zwicker et al., 1999). The role of technology in implementing the science standards cannot be ignored in science classrooms (Krajcik, Marx, Blumenfeld, Soloway, & Fishman, 2000). On-line data provides the opportunity to conduct authentic learning situations, which allow students to practice the way scientists do science, including “planning, making observation, hypothesizing, experimenting, collecting and analyzing data, proposing explanations, and communicating results” (Lee & Songer, 2003, p. 925).

The current study utilized inquiry-based instruction to teach tides with the preservice teachers. The instruction applied an oceanography approach which was based upon a realistic model as opposed to an astronomy model, which uses a hypothetical model to describe tides. In the oceanography model, tides are explained at a particular location with the data collected at that location and predictions made by the students generally fit the data. Since tides are described with the support of real data in the oceanography model, inquiry-based instruction seems to be the model that best fits the teaching of tides for this study. In addition, the inquiry-based instruction makes science more meaningful within an authentic environment, students build relationships with the subject (Songer, 1998), and students are highly motivated to engage in inquiry-based instruction supported by technology (Krajcik, Simmons, & Lunetta, 1988). The National Science Education Standards also encourage more emphasis on inquiry, in which students can investigate the everyday world around them, and less emphasis on memorizing decontextualized knowledge (NRC, 1996).

### *On-line Data*

Computers have become an important part of scientific investigations in the last two decades. They play an important role in collecting data, analyzing data, modeling, sharing findings, and storing data (Edelson, 2001). Computers are also being used extensively in teaching and learning. The positive effects of computers for science classes were reported previously in: 1) a review study, which looked at Internet usage in K-12 classrooms (Kuiper, Volman, & Terwel, 2005), and 2) a meta analysis study (Bayraktar, 2002), which investigated the effectiveness of computer-assisted instruction in science classes. The Internet especially provides many educational applications for the science classroom (Kuiper et al.). Increased usage of the Internet for communication, sharing of information, reaching remote or archived data, and obtaining other instructional materials are critical applications of the Internet in K-12 classrooms (Hoffman, Wu, Krajcik, & Soloway, 2003; Songer et al., 2002; Wallace, Kupperman, & Krajcik, 2000).

In a research study with 230 middle school students from six classes and their teachers, Songer (1996) investigated technology-rich inquiry within a Web-based environment. Songer implemented a curriculum program titled KGS (Kids as Global Scientist). In this curriculum, students collect data, discuss the data, develop explanations, share the findings, and make real-time weather predictions. Both the control and Internet groups demonstrated significant content and inquiry gains, but the Internet group showed greater ability to predict weather at distant sites than the non-Internet group. In other words, they were able to apply their learning to other situations. Students

took more control of their learning and inquiry. This study also reported that Web-based inquiry positively affects students' motivation. In another research study with 830 middle school students, Hoffman et al. (2003) investigated science content understanding with the use of on-line resources. The study used a curriculum material titled MYDL (Middle Years Digital Library). MYDL provides both printed and on-line material to support inquiry. They found that students constructed meaningful understanding through using on-line data. Also, they found that if students used search strategies appropriately, they could benefit more from on-line activities. Therefore, teacher support is suggested as a necessary element of on-line inquiry to guide search strategies. These two research studies and other studies which utilized Internet or Web resources for instructional purposes tend to put the students into the role of scientists. These studies were designed so that students could do scientific inquiry in the same way as a scientist. From data collection to analyzing and reporting findings, each activity was conducted in an authentic environment where students did scientific inquiry using on-line resources. Positive effects of authentic science activities are previously reported by Lee and Songer (2003). In a research study with 59 6<sup>th</sup> grade students who performed in a real-time forecasting situation using on-line data in an authentic scientific activity, students developed rich content knowledge and the skills to do scientific inquiry.

The Web offers so many advantages for classroom inquiry (Trundle, in press; Windschitl, 1998). Web-based inquiry activities allow students to access existing data sets, to access up-to-date information, and to communicate with peers and experts (Bell & Linn, 2000; Bozdin, 2002; Lee & Songer, 2003). Web-based inquiry can promote

motivation and improve communication, knowledge, and knowledge refinement (Edelson, 2001; Songer, 1996; Songer et al., 2002). Also, it was observed that students tend to develop the skills to work independently of the teacher (Etkina et al., 2003). When the teacher is not perceived as the primary knowledge source, students take responsibility for their learning (Etkina et al., 2003 ; Songer, 1996). In other words, students become scientists by themselves.

Using the Internet in classrooms can support learning but there are technical and economic limitations associated with the Internet-based instruction. Some of the drawbacks include computer shortages, bad connections, old technology, and ineffective Internet use. In addition to these logistics problems, there are also pedagogical issues related to Web-based instruction. When students search by themselves, they usually end up with many unrelated or inappropriate pages and sources, and they waste time trying to locate appropriate sites (Hoffman et al., 2003; Wallace et al., 2000). The main point here is that students can use the Internet but have a hard time finding the appropriate sources. Wallace et al. looked at 6<sup>th</sup> grade students in science classes as they used the Web to carry out an inquiry-based assignment. They found that the students used the Web easily but simplistically. The students did not use the Internet beyond the very simple search features of the Web. Wallace et al. reported that Web browsing is easy for 6<sup>th</sup> grade students who can learn the hyperlinks and navigations. In addition, students seek answers rather than try to understand the content when they are allowed to freely search the Internet (Hoffman et al.). Giving students the URL or giving the appropriate key words for the Internet-based activities helps prevent students from wasting time, coming across

inappropriate content, or ending-up with an overwhelming quantity of information (Hoffman et al.). Songer et al. (2002) observed six values in Web-based inquiry instruction, including “relevance, student content and inquiry learning, learning by special population, teacher learning, enthusiasm, and fluency with technology” (Songer et al.). These values summarize the challenges students and teachers may face when Web-based instruction is utilized.

Despite these drawbacks, studies provide evidence that on-line inquiry is effective at increasing students’ understandings of scientific content as long as students are provided with enough support (Lee & Songer, 2003) and directed toward thoughtfully selected, relevant resources (Hoffman et al., 2003; Windschitl & Irby, 1999). Educators recommend that teachers should encourage discussion about the information that the students come across on the Internet (Hoffman et al.). Appropriate discussions would help the Web-based inquiry be more effective and also save both students and teachers a lot of valuable instruction time.

Several empirical studies have investigated Internet-based inquiry for different purposes. The foci of the studies included: conducting a search on the Internet for problem-solving activities (Lin, Cheng, Chang, & Hu, 2002), reporting the locally collected or archived data and sharing this with other students and scientists (Beaujardiere et al., 1997; Etkina et al., 2003; Post-Zwicker et al., 1999), communicating and sharing when working on coordinated on-line projects (Edelson, 2001; Lee & Songer, 2003; Songer, 1996), and investigating students’ interaction with the Web and students’ use of the Internet (Hoffman et al., 2003; Wallace et al., 2000).

In general, the Internet is increasingly being used in science classes as an information source and as a tool to process information because it provides access to enormous amounts of information and because of its attraction to students (Kuiper et al., 2005; Moore & Huber, 2001). The instructional intervention carried out in the current study was directly aimed at the use of an authentic activity for learning about tides. For authenticity, participants were required to access real-life data collected and stored by professionals from distinctive parts of the world. Basically, the main use of the Internet in the current study was to gather data from an archived data source to make the activity more meaningful and to give students ownership of the knowledge (Songer, 1998). In addition to data collection, computers were used to examine the data and build models to explain the tides. Those applications also were conducted in a way similar to how scientists might examine the data. These computer activities and Internet applications placed the students in a position in which they were functioning as real scientists trying to explain a natural phenomenon. After these activities, participants were given the opportunity to explore using computer animations in order to understand the phenomena better. Research has shown that use of real-time data and firsthand information through the use of the Internet can increase student understanding (Songer).

In summary, inquiry-based and technology enhanced instruction was applied because it has been previously reported that printed media has limitations in tides instruction because it includes gravity, rotation of the Earth on its axis, and moon phases. In addition, instruction which explains tides should include experiences in three-dimensional space. Inquiry-based and technology-enhanced instruction appeared to have

potential to diminish the limitation of printed media in tides instruction. Participants had the opportunity to conduct scientific investigation in a way the similar to that of scientists. The participants need the opportunity to develop their own model and later to see the original model in a simulation environment. Vosniadou's conceptual change model was applied to construct the theoretical framework of the current study.

Vosniadou's conceptual change model and the instructional approach used in the current study fit together well for several reasons. According to Vosniadou, learning in school requires students to complete the skills such as making observations, memorizing, understanding, predicting, analyzing the data, interpreting, and applying the new knowledge in other situations. These skills could not be developed without students' active involvement in their learning (Vosniadou, 2001a). The current study specifically followed two of the Vosniadou's (2001a) learning perspectives. The first one is that the learner construct their own knowledge. The second one is that application of real-life situations is important for meaningful learning. Both suggestions reflect the findings of research studies from science education and from the cognitive psychology perspectives over the last few decades. Therefore, the instructional intervention that was inquiry-based and technology-enhanced was selected and implemented in this study.

## CHAPTER 3

### METHODOLOGY

#### Introduction

The purpose of this two-phase sequential mixed-method (Creswell, 2003) study was to describe and understand preservice teachers' conceptions of tides and to explore an instructional strategy that might promote the learning of the related scientific concepts. More than one type of qualitative data was collected to triangulate the findings and a test was administered to quantitatively explore achievement of content knowledge related to tides. More specifically, this descriptive and exploratory study was designed to help researchers better understand preservice teachers' conceptual understandings of tides and the relationship of an instructional unit, which included inquiry-based, technology-enhanced instruction to preservice teachers' understandings. This chapter explains the (a) context and participants, (b) structure of the instructional intervention, (c) data collection procedures, (d) data analysis, and (e) the elements contributing to the trustworthiness.

## Context and Participants

The students recruited to participate in this study were preservice teachers in three initial licensure programs at a major Midwestern research university. A total of 80 graduate students, 18 (22.5 %) male and 62 female (77.5%), in secondary, middle, and early childhood education programs completed a multiple-choice assessment of their knowledge of tides-related concepts. A subset of 30 volunteers from the 80 participants was interviewed before the instruction. The other 50 of the 80 students chose not to participate in the interview and instruction. A subset of 19 of the 30 students who were interviewed subsequently agreed to participate in the instruction and these students were interviewed again after the instruction. All of these 19 students also completed the tides achievement pre-test and 18 of the 19 students completed the post-test multiple-choice assessment to measure scientific knowledge of tides. Eleven of the 30 students who were interviewed before the instruction chose not to participate in the instruction and 12 did not complete the post-test. The number of participants for each type of data collected is presented in Table 3.1.

All the interviews were conducted in an interview room which was located in the same building where the participants were taking their methods courses. The pre-test and post-test measures of the achievement related to tides and other content were administered during the methods course with the permission of the instructor. A computer laboratory was used during the instruction. Each participant had access to a personal computer, the Internet, and Excel spreadsheet software. The computer room was also equipped with an LCD projector which occasionally was used during the instruction.

Group	Pre- instructional Interview (n=30)	Post- instructional Interview (n=19)	Pre- test (n=80)	Post- test (n=18)	Type of Instruction on tides.
No- instruction group	11	0	61	0	No instruction
Instruction group	19	19	19	18	Inquiry-based and technology- enhanced instruction

Table 3.1: Number of participants and each type of data collected

### Structure of Instructional Intervention

The effectiveness of Web-based inquiry for science teaching was discussed in Chapter 3. The instructional intervention of this study was based on the literature related to inquiry and technology applications in education. Also, the wide availability of computers and Internet access in science classrooms allowed the researcher to apply these technological features of instruction. For example, Hartel (2000) indicated that “Dynamic

system is difficult to explain when the explanation is restricted to print media.” Thus, inquiry-based and technology-enhanced instruction was used for the instructional intervention. Also, the integration of technology into the astronomy instruction has been found to be effective with other astronomy concepts, such as moon phases (Trundle & Bell, 2005).

Between the pre and post multiple-choice assessments of achievement of tides concepts, the instruction group participants were taught with an inquiry-based technology-enhanced instruction. The instruction followed a textbook chapter, titled “Discovering Tidal Patterns” (Trundle & Krissek, 2005). Preservice teachers used computer simulations and visualization tools such as graphs to investigate the tides and the causes of tides. In addition, preservice teachers accessed and used actual on-line data to interpret the tidal patterns and describe the relationship of tides to moon phases. The total amount of time spent for instruction was 3 hours. The first step of the instruction was to gather and analyze tidal data from a predetermined Web page. Participants extracted a chunk of raw data from this Web source, imported these data into an Excel spreadsheet, and organized the data with the basic features of Excel spreadsheet software, such as cutting, pasting, adding, subtracting, and graphing. After organizing the data, participants created and interpreted line graphs of tides and tidal ranges from the data set. The next step involved participants using another Web page to identify the moon phases for the same time period. By cutting and pasting, images of moon phases were transferred and aligned to the line graphs which had been prepared previously. Participants correlated the moon phase data with the tidal range graphs and tried to describe the

relationships between tides and moon phases. By integrating these two phenomena, participants modeled and hypothesized the causes of tides. This process was repeated for different geographic locations in order to see variations in tidal data. Through a model demonstration with a hula hoop, and through a Web animation (Trundle & Krissek), participants put their knowledge together into three dimensional environments to construct an explanation for the cause of tides. The sequence of the instruction is presented in Table 3.2.

Time (minute)	Task	Activity
60 min	Gathering and organizing tidal data	Preservice teachers used Excel spreadsheets to import, organize, and graphically represent data; calculate daily tidal ranges
60 min	Correlating tides with moon phases	Preservice teachers described the relationships between moon phases and tides
30 min	Comparing tidal data from different geographic locations	Preservice teachers inferred conditions that contribute to variations in the data
30 min	Explaining tides	Preservice teachers modeled tides with an on-line, computer applet and with a physical model

Table 3.2: Summary of the inquiry-based and technology-enhanced instruction and allocated time

### Data Collection Procedures

Data were collected before and after the instruction. Data were collected using both qualitative and quantitative data collection methods (Gay, 1996) in order to address the research questions. The types of data collected are presented in Table 3.3. Data were collected in the following order: pre-instruction interviews were conducted with 30 participants, 80 participants completed the pre-instruction achievement test on tides, 19 participants completed the instruction and wrote their journals entries, 19 participants completed the post-instruction interview, and 18 completed the post-instruction achievement test. A description of the data collection methods follow.

Qualitative data	Quantitative data
1. Pre-interview of conceptual understanding of tides with preservice teachers	1. Pre-test of achievement of tides and related concepts
2. Post-interview of conceptual understanding of tides with preservice teachers	2. Post-test of achievement of tides and related concepts
3. Preservice teachers' journal entries	
4. Handouts	

Table 3.3: Qualitative and quantitative data collected

## *Qualitative Data*

### *Pre- and Post-interviews with Preservice Teachers*

Structured interviews (Glesne, 1999) were conducted with preservice teachers before and after instruction. The structure of the interview protocol for the preservice teachers was based upon the interview protocol developed by Trundle et al. (2002), because of the overall study similarities and similarities in content between this study and Trundle et al.'s study. Both studies investigated an astronomy concept with preservice teachers. The interview was comprised of various types of tasks including drawing, responding to structured open-ended questions, and using models. Preservice teachers used models of the Earth, moon, and sun in order to explain their answers to questions about what causes tides. Because two-dimensional models usually provide preservice teachers with only one perspective, which is an Earth perspective (Keating, Barnett, Barab, & Hay, 2002), three-dimensional models were used during the interview. With the three-dimensional models observers not only see the Earth viewers' perspective, but other perspectives as well. Trundle et al. (2002) found that using a three-dimensional model did not have any detectable instructional value during an interview about moon phases with preservice elementary teachers. Another reason to use three-dimensional models was that the understanding of tides requires a good understanding of the Earth-moon-sun system in three-dimensional space (Hartel, 2000), and the three-dimensional model used in this study provided the students with an example that more nearly approximates the causes of tides in the three-dimensional Earth-moon-sun system. By using a three-dimensional

model, preservice teachers had an opportunity to demonstrate perspectives other than the Earth perspective. The content validity of the interview questions was judged by two experts, one a science educator and the other an oceanographer. The content of the protocol was judged to be accurate and appropriate for assessing the major points related to understanding tides.

During the interview, preservice teachers first were asked about their experiences with tides so as to break the ice between the researcher and interviewees, and then the participants were asked to explain the causes of tides. After that, students were asked to draw a model to explain the causes of tides based on their previous experiences. In the second part of the interview, the preservice teachers were provided a model of the Earth, sun, and moon to aid them in their descriptions if the participant mentioned these objects. Then, the preservice teachers were asked additional questions about tides, which they could answer with or without arranging the models. The purpose of the interview was to obtain in-depth knowledge of preservice teachers' understandings of tides and the causes of tides and to describe any alternative conceptions they held before and/or after instruction.

Additional probing questions were asked based on the preservice teachers' answers. Probes included questions like "What do you mean? Tell me a little bit more. Why do you think so?" The interviewer tried to rephrase what the participants said. No time limit was set for the interview, but each interview generally lasted about twenty minutes. All of the interviews were videotaped and audio-recorded. The interview protocol is included in Appendix A.

## *Document Collection Procedures*

### *Journal Writing*

Preservice teachers (n=19) were asked to write a short journal after the instruction. The purpose of the journal was to gain insight into preservice teachers' perceptions of the instruction and to receive feedback from participants related to their content understanding or any alternative conceptions developed during the instruction. The approximate time required to write this journal entry was less than 10 minutes. The format for the journal is included in Appendix C.

### *Handouts*

Before beginning the tides instruction, participants were provided handouts to record their work during the instruction. Before the instruction, participants were asked to write down their understandings of tides on this handout. During the instruction, they kept notes on their interpretation of line graphs, correlation between the moon phases and line graphs, and causes of tides. The participants' handouts were collected after the instruction, copies were made, and the original documents were returned to the participants for their own records.

### *Quantitative Data*

An assessment of achievement related to tides was developed by the researcher. The test was based on the results of previous research studies on various astronomical

phenomena (Galili & Lehavi, 2003; Hartel, 2000; Viiri, 2000a; Viiri, 2004). The same test was used for both the pre-test and post-test. The test included questions related to the shape of the Earth and solar system (4 questions), gravitational forces (5 questions), and tides and the causes of tides (10 questions). The questions measured content related to the tides instruction. The test included 19 items and the content validity of the test questions was judged by an oceanographer. Questions were approved to be valid questions to measure the major points related to understanding the tides. All 80 preservice teachers completed the tides achievement pre-test after the pre-interviews and 18 of the 80 completed the post-test after post-interviews. Comparison of pre- and post-test results was used to assess preservice teachers' gain score, which is obtained by subtracting tides achievement pre-test scores from post-test scores. Reliability of the test was measured with Cronbach Alpha and it was .71 for the entire test. A copy of the instrument is provided in Appendix B.

## Data Analysis

### *Qualitative Analysis*

The first step in the qualitative data analysis was to transcribe the video and audio tapes. Transcriptions were made by the researcher in order to prevent the loss of information during the transcription process and to gain more in-depth insight into the data. After the transcriptions were completed, these transcripts were read two to three times before any coding was done by the researcher. After the researcher obtained a general idea about the data, the transcripts were read again and important points were

marked by the researcher before starting to develop codes based on the participants' responses.

The constant comparative method was used to analyze the qualitative data. The constant comparative method was originally developed for use in the grounded theory methodology by Glaser (1965) and Glaser and Strauss (1967). The main purposes of the constant comparative method are to generate theory more systematically through "joint coding and analysis" (Glaser, p.437) and to compare qualitative data from all participants, including those whose understanding is in a similar category and those in different categories. In order to develop conceptual categories among various data sources (Boeije, 2002; Charmaz, 2000), the constant comparative method continuously questions, compares, and delimits the data (Glaser ; Glaser & Strauss).

The constant comparative method unites two general approaches to data analysis in qualitative research. The first approach tries to convert qualitative data into a quantifiable form and the second approach tries to generate theoretical properties (Glaser, 1965). Glaser said the constant comparative method is "combining the explicit coding procedure of the first approach and the style of theory development of the second" (p.437). By combining the two traditional approaches, conceptual categories extracted from the interview can be generated more systematically.

In the Handbook of Qualitative Research, Charmaz (2000) summarized the constant comparative method under five categories; "(a) comparing different people, (b) comparing data from the same individuals with themselves at different points in time, (c) comparing incident with incident, (d) comparing data with category, and (e) comparing a

category with other categories (Charmaz, 1983, 1995c; Glaser, 1978, 1992)” (p.515). The number of categories used for the analysis is determined by the data and these categories do not have to form a linear process (Boeije, 2002). For this study, comparisons were made at five levels, which are presented in Table 3.4.

Comparison	Aim of comparison
Data from a single interview were compared to the coding scheme.	To verify the consistency of answers, to code the transcripts, and to add new codes.
Codes were compared within each interview.	To determine the alternative and scientific conceptions.
Codes within a single interview were compared to types of conceptual understandings.	To categorize participants based on their conceptual understandings.
Comparisons were made between the participants’ conceptual understandings.	To summarize the overall conceptual understanding categories with percentages.
Comparisons were made between the conceptual understandings before and after instruction.	To distinguish conceptual change.

Table 3.4: Five levels of comparisons for the analysis of qualitative data

The constant comparative method was an appropriate method because this study was mainly descriptive and exploratory in nature. Glaser (1965) pointed out the characteristics of the constant comparative method for the exploration and description of the data “constant comparison method is concerned with generating and plausibly

suggesting (not provisionally testing) many properties and hypotheses about a general phenomenon” (p.438). In other words, the constant comparative method is effective at describing and exploring a phenomenon.

Similar to all qualitative data analysis methods, coding is an important process in the constant comparative method. It is easy to form categories and analyze the data when the data are coded thoroughly (Charmaz, 1983; Strauss & Corbin, 1990). Also, researchers can see new perspectives during the coding. These new perspectives shape researchers’ emergent codes (Charmaz, 2000).

Three coding strategies, open, axial, and selective coding, were used during the constant comparative method. Open coding, which is also called initial coding, was used to dissect the interview responses and other documents line by line and word by word (Charmaz, 2000). Through open coding, concepts were identified and their properties were discovered in the data (Strauss & Corbin, 1990). Following the open coding, axial coding was performed to relate categories to their subcategories (Charmaz; Strauss & Corbin). Selective coding was used to sort initial and axial codes in order to integrate and refine the bigger categories (Charmaz; Strauss & Corbin). The categories obtained from these coding processes clustered around each research question and helped the researcher to answer the research questions.

Memo writing by the researcher was performed during the coding in order to address how the coding process was performed, what the criteria were for making decisions about the coding, and any other issues which might be useful during the

analysis or category development. In addition, memos were used to help build a bridge between the coding and interpretation of the findings (Charmaz, 2000).

Previous research (Galili & Lehavi, 2003; Viiri, 2000a) was helpful in identifying the codes used to describe scientific and alternative conceptions that participants might have. Literature-based codes were predetermined in order to start the initial coding and the overall analysis. The literature-based codes, used in this study, mainly were used during the selective-coding process to give ideas about the identification or classification of a concept as either scientific or alternative. Also these codes were helpful for obtaining a standard way of abbreviation for codes. Any additional codes which emerged during the coding process were added to the coding map. The codes and their definitions used in this study are presented in Table 3.5.

Categorization of alternative and scientific conceptions was based on the same categorization developed by Trundle et al. (2002), who coded conceptual understandings under four major categories: scientific, scientific fragments, alternative, and alternative fragments. Scientific models, which are also called consensus models, coincide with current scientific views (Vosniadou, 1991). Four critical elements were required for a scientific understanding and are presented as the first 4 codes in Table 3.5. If the participants' responses included all four of the criteria defined as Scientific without showing any alternative conceptions, their responses were coded as a scientific understanding. On the other hand, if a participant showed a subset of the four scientific criteria, the participant's response was categorized as scientific fragments. Previous research indicated that students can hold fragmented scientific models of tides (Galili &

Lehavi, 2003; Hartel, 2000; and Viiri, 2000a). Participants' responses were categorized as scientific fragments with

Code	Definition of code
Sci_GRA	Gravitational force of the moon and the sun causes tides.
Sci_CENT	Centrifugal forces created through the Earth's and the moon's rotation around a center of common mass is the main reason for the bulge which is on the side of the Earth farthest away from the moon.
Sci_ROT	Rotation of the Earth on its axis is the reason why we have two high and two low tides in each day.
Sci_TWO	There are two high tides at the same time on the opposite sides of the Earth and two low tides also at the same time on the opposite sides of the Earth from each other.
Alt_GRA	Gravity of the moon causes the water to pile up on one the side of the Earth and recede on the other side.
Alt_TIME	Occurrence of tides is related to the time of day (e.g. day is low tide and night is high tide) or appearance of the sun and the moon in the sky (e.g. when the sun is up we have low tides and when the moon is up we have high tides).
Alt_MOON	The moon causes one tidal bulge and rotation of the moon around the Earth during one 24-hour period causes the tides to move with the moon.
Alt_OTHER	Tides are caused by rain, wind, and Earthquakes. Participant does not mention the Earth, moon, sun, gravity, or centrifugal forces.

Table 3.5: Codes and their definitions

alternative fragment if they held a subset of scientific conceptions along with an alternative conception. Participants' responses that were categorized as scientific fragments with alternative fragment included a two-tidal bulge model in addition to other scientific criterion. These responses are closer to being scientific than to being alternative.

Alternative conceptions are models which are different than the scientific model (Vosniadou, 1991). Learners may obtain alternative concepts intuitively through their everyday experiences or when their intuitive conceptions conflict with scientific conceptions (Vosniadou & Brewer, 1992, 1994). Responses were categorized as alternative fragments if the responses included a subset of different alternative conceptions at the same time. Previous research indicated that students can hold alternative conceptions based on either a one- or two-tidal bulge model (Viiri, 2000a). Categorization of participants' conceptual understandings is presented in Table 3.6.

Types of Conceptual Understandings	Criteria for identification
Scientific	Includes all four critical elements 1. Gravitational force of the moon and the sun causes tides. 2. Centrifugal forces created due to the Earth and the moon's rotation around a center of common mass is the main reason for the bulge which is on the side of the Earth farthest from the moon. 3. Rotation of the Earth on its axis is the reason why we have two high and two low tides in each day. 4. There are two high tides and two low tides at the same time on opposite sides of the Earth.
Scientific Fragments	Includes a sub-set but not all of the four scientific-critical elements without holding any alternative conceptions.
Scientific Fragments with Alternative Fragment	Includes a sub-set but not all of the four scientific-critical elements along with an alternative fragment.
Alternative	Conceptual models which are different than the scientific models (Vosniadou, 1991) which are obtained through learners' every day experiences intuitively or when their intuitive conceptions conflict with scientific conceptions (Vosniadou & Brewer, 1992, 1994)
Alternative Fragments	Includes a subset or subsets of alternative conceptual understandings

Table 3.6: Types of conceptual understandings and criteria for identification

### *Quantitative Analysis*

Quantitative data were analyzed to understand preservice teachers' understandings of tides by assigning each scientific response to the tides achievement test

items a score of one and each nonscientific answer a score of zero. The same scoring format was used for both pre-test and post-test responses. Statistical procedures in the Statistical Program for the Social Sciences (SPSS Version 14.0 for Windows) were used to analyze responses to the pre-test and post-test questionnaire, and the quantified alternative and scientific conceptions from interview responses.

To assess whether the entire tides achievement test of 19 items (which were summed to create the achievement score) formed an internally consistent scale, Cronbach's alpha was computed. An independent t-test was applied to compare tides achievement pre-test scores of participants who were interviewed and took the instruction with scores from the rest of the participants who were not involved in the instruction to check whether there was a significant difference between the instruction group and non-instruction group before the instruction. A paired-sample t-test was conducted to investigate the changes of achievement test scores of tides and related concepts for the instruction group after the instructional intervention. The Pearson product-moment correlation coefficient was applied to analyze the relationships between and among the occurrence of alternative conceptions, scientific conceptions, and the pre-test achievement items on tides. In addition to t-tests and simple linear correlation analysis, a stepwise forward multiple regression analysis was conducted to determine the best linear combination of pre-test items for predicting the gain in test scores. A stepwise regression was applied to gain scores as a dependent variable and pre-test scores as independent variables. A gain score was obtained by subtracting the pre-test scores from the post-test scores.

The difference between the proportions of types of conceptual understandings categorized as alternative and alternative fragments between the group of 30 and the subgroup of 19 preservice teachers was assessed with a z-score (Ferguson, 1966). This method presented by Ferguson (1966, p.176) was applied to calculate the z-score in order to find whether or not a significant difference existed between the group of 30 and subgroup of 19 preservice teachers on the proportions of alternative and alternative fragments before the instruction. The calculation suggested by Ferguson follows (p.177).

$$Sp_{1-p_2} = \text{square root } [pq (1/N_1+1/N_2)]$$

$$p=(f_1+f_2) / ( N_1+N_2)$$

$$q=1-p$$

$$p_1=f_1/N_1$$

$$p_2=f_2/N_2$$

$$Z= (p_1-p_2) / Sp_{1-p_2}$$

p=sample value of proportion.

p<sub>1</sub>=proportion of first sample

p<sub>2</sub>=proportion of second sample

### Trustworthiness

Trustworthiness or research validity was carefully considered during the data collection and data analysis processes. Trustworthiness, defined as the extent to which one can believe in the research findings (Glaser & Strauss, 1967) or “worth paying attention to, worth taking account of” (Lincoln & Guba, 1985, p. 290), was established

through credibility, transferability, dependability, and confirmability of the data collection and analysis. These four terms are suggested by Lincoln and Guba as the equivalents for the conventional terms internal validity, external validity, reliability, and objectivity.

The credibility of the study was achieved through three activities: prolonged engagement, persistent observation, and triangulation (Lincoln & Guba, 1985). Prolonged engagement is described as “the investment of sufficient time to achieve certain purposes: learning the culture, testing for misinformation introduced by distortions either of the self or of the respondents, and building the trust” (Lincoln & Guba, p.301). The researcher knew the participants from their previous methods classes because the researcher was a doctoral student in the same department. In addition, the researcher worked with this group of participants in previous quarters on a different research project. The researcher observed participants’ methods courses once a week for two quarters for a total of 20 weeks. Also, the researcher spent a significant amount of time during data collection and instruction with the participants. This history between the researcher and participants established a prolonged engagement. The second activity to achieve credibility was the persistent observation, which “provides depth” to the data (Lincoln & Guba, p.304). Right after the interviews, the researcher generated reflective notes to describe the interview responses in more detail. Audio and video recordings were also used right after the interviews to make detailed notes. The third activity to achieve the credibility was triangulation, which was achieved by using two or more sources of data such as journals,

handouts, and interviews, and through the data-collection methods of interviews and multiple-choice assessments as suggested by Lincoln and Guba.

Transferability is very hard to establish in qualitative studies (Lincoln & Guba, 1985). Lincoln and Guba describe it as “not the naturalist’s task to provide an index of transferability; it is his or her responsibility to provide the data base that makes transferability judgments possible on the part of potential appliers” (Lincoln & Guba, p.316). In this study, the researcher tried to establish transferability by providing a thorough and detail description of codes and the coding process. Also, the transferability of the instruction is established through use of a published book chapter for instruction (Trundle & Krissek, 2005), which can be accessed and replicated by any researcher. In addition, the use of a structured interview protocol established potential for the transferability of the study as well.

Dependability, which is the counterpart of the reliability in quantitative study (Lincoln & Guba, 1985), was achieved with the other activities applied for the credibility and transferability, such as prolonged engagement, persistent observation, triangulation, and detailed description for replication of the study in different settings. Also, dependability was established here through the presentation of methodology and student learning with detailed description. Preparing detailed reflective notes after the interview and instruction and keeping memos during data collection and coding contributed to the dependability of the study. In addition, inter-rater reliability was used to demonstrate the dependability of the coding. A total of 25 % of interview transcripts from both pre-interviews and post-interviews were randomly selected. The researcher and another

graduate student, who was trained on how to code the data, coded the selected data. Inter-rater agreement for participants' scientific or alternative conceptions was 83 % between the two coders. However, simple percentage agreement is considered a weak method to assess inter-rater agreement (Krippendorff, 2004; Lombard, Snyder-Duch, & Bracken, 2002). A more conservative method is Cohen's kappa (Cohen, 1960), which was used to determine the agreement between the two observers. Cohen's kappa was  $\kappa = .77$ , indicating an acceptable level of agreement between the raters.

Confirmability, or what is called objectivity in quantitative research (Lincoln & Guba, 1985), was achieved using similar methods to those for dependability. For example, triangulation and keeping of a reflective journal by the researcher (Lincoln & Guba) were the methodologies employed to contribute to the confirmability of the study.

## CHAPTER 4

### ANALYSIS OF DATA

#### Introduction

The purpose of this mixed method study was to describe and understand preservice teachers' conceptions of tides and to explore an instructional strategy that might promote the learning of scientific concepts. This chapter reports the analysis of data from the qualitative findings and the quantitative results. Findings and results are presented in two categories; Qualitative Findings and Quantitative Results. Both sections address the following four research questions.

1. What are the types of conceptual understandings held by preservice teachers about the cause of tides?
2. What are the conceptual understandings held by preservice teachers about tides before completing an inquiry-based technology-enhanced instruction including the study of tides?
3. What are the conceptual understandings held by preservice teachers about tides after completing an inquiry-based technology-enhanced instruction including the study of the tides?

4. How do preservice teachers' types of conceptual understandings of tides differ after completing an inquiry-based technology-enhanced instruction including the study of tides?

### Qualitative Findings

As described in chapter 3, the videotaped interviews were transcribed, coded, and analyzed to answer the research questions. First, the tapes were transcribed by the researcher. Then these transcripts were read two to three times without doing any coding. After the researcher obtained a general idea about the data, the transcripts were read again and important points were marked by the researcher before starting to develop codes based on the participants' responses to interview questions, use of models, and use of drawings. The codes, specified in chapter 3, were used during the coding process. New codes emerged from the interviews within this particular group of participants and the new codes were added to the coding scheme. After the coding was completed, participants' responses were grouped by type of conceptual understanding. Six predetermined categories for the type of conceptual understanding including scientific, scientific fragments, scientific fragments with alternative fragment, alternative, and alternative fragments were used. These were the conceptual categories which were developed previously by Trundle et.al, (2002). These categories were used because they fit this study and the data very well. In this categorization, participants' responses were separated into different conceptual categories and also further analyses were performed to

look for different patterns or combinations in terms of alternative and scientific conceptual understanding.

The constant comparative method (Glaser & Strauss, 1967) was applied to analyze the qualitative data. Comparisons were made at five levels: first, data from a single interview were compared to the coding scheme described in chapter 3; second, codes were compared within each interview; third, codes within a single interview were compared to types of conceptual understandings; fourth, comparisons were made between the participants' conceptual understandings; and fifth, comparison were made between the conceptual understandings before and after instruction. Findings from the qualitative data are presented in the following order: Findings for the Types of Conceptual Understandings, Findings for Before and After Instruction, Changes in Conceptual Understandings, and Summary of Qualitative Analysis.

### *Findings for Types of Conceptual Understandings*

In this section, the overall types of conceptual understandings held by preservice teachers before or after inquiry-based and technology-enhanced instruction are discussed in response to the first research question. Six types of conceptual understandings, namely, scientific, scientific fragments, scientific fragments with alternative fragment, alternative, and alternative fragments are presented with the excerpts from the participants' interview transcripts.

***Research Question 1: What are the types of conceptual understandings held by preservice teachers about the cause of tides?***

### *Scientific*

In order to have a scientific understanding of tides, participants were expected to consistently express in detail through verbal explanations, use of three-dimensional models, and with drawings all of the four scientific criteria, which were defined in Chapter 3. All of the participants identified as having a scientific conceptual understanding indicated that they understood that there are two high tides at the same time on the opposite sides of the Earth and two low tides also at the same time on the opposite sides of the Earth from each other (Sci\_TWO), gravitational forces from the sun and from the moon cause the tides (Sci\_GRA), centrifugal forces created through the Earth's and the moon's rotation around a center of common mass is the main reason for the bulge which is on the side of the Earth farthest away from the moon (Sci\_CENT), and the rotation of the Earth on its axis is the reason why we have two high tides and two low tides in each day (Sci\_ROT). None of the participants held an understanding that was categorized as scientific before the instruction. However, ten participants (numbers 102, 103, 104, 111, 114, 116, 120, 126, 127, and 129) from the sample of 19 preservice teachers held a scientific understanding of tides after completing the instruction.

The following excerpt from participant 103's post-interview responses provides a representative example of a scientific conceptual understanding. Responses that were coded as scientific are presented with the related codes. This participant's post-interview responses to the interview questions follow.

Researcher: Can you tell me what you know about tides in general?

103: I just know that it is caused by the gravitational pull of the moon and the sun (**Sci\_GRA**).

Researcher: Can you tell me a little bit more?

103: As the moon here (*Participant used his right fist as the model of the moon*), the moon is pulling on the water of the ocean and causes tides. And, um, depending on where the moon is in relation to the sun and the Earth (*Participant revolved the right hand around the left hand*), depends on how much the pull is in any given area (**Sci\_GRA**).

Researcher: What do you think causes the tides?

103: The gravitational pull (**Sci\_GRA**) and the centrifugal forces (**Sci\_CENT**) between them. It is caused by the Earth's rotation and the pull of the moon and a little bit of pull of the sun.

Researcher: Can you tell me a little bit more about centrifugal force?

103: Centrifugal force is like as an object spins, the natural instinct of the material decides to go outward along the motion and that causes the force. So if you have to pull in one way centrifugal force because of the Earth rotation causing the same things on the other side due to force it is spinning (**Sci\_CENT**).

Participant 103's interview responses indicated that he held a scientific understanding of gravitational pull of the sun and the moon, and the centrifugal forces, which cause the tides. After the participant explained about the gravitational and centrifugal forces, he was asked to draw his model of tides from an astronaut perspective. An excerpt from the transcript where he explains and discusses his drawings follows.

Researcher: Imagine that you are an astronaut and traveling in a space rocket around the Earth. At some point you have looked at the Earth and you recognized the tides. From an astronaut perspective, draw what you would see of the Earth and label the picture with your explanation.

103: This is the Earth and I am out of space (*Participants' drawing presented in Figure 4.1*).

Researcher: Can you tell me about your drawing?

103: I am looking at it if the moon is right here (*Participant pointed to the moon on his drawing*), I am seeing the water. It kind of makes bulge almost like crescent comes in one point and gradually slides down. I see the moon over here and then I see the ocean right here (*Participant pointed to the bulge which is on the side of the Earth facing the moon and labeled as H*) and I see another bulge here (*Participant pointed to the bulge which is on the side of the Earth farthest away from the moon and labeled as H*). I noticed just very

little bit bulges here (*Participant pointed to the sides of the Earth which is not facing the moon, labeled with L*) (**Sci\_TWO**).

Researcher: What do you call those bulges?

103: Those are the tides. High tides (*Participant pointed to the Hs on the drawing of the Earth*) and these are low tides (*Participant pointed to the Ls on the drawing of the Earth*) (**Sci\_TWO**).

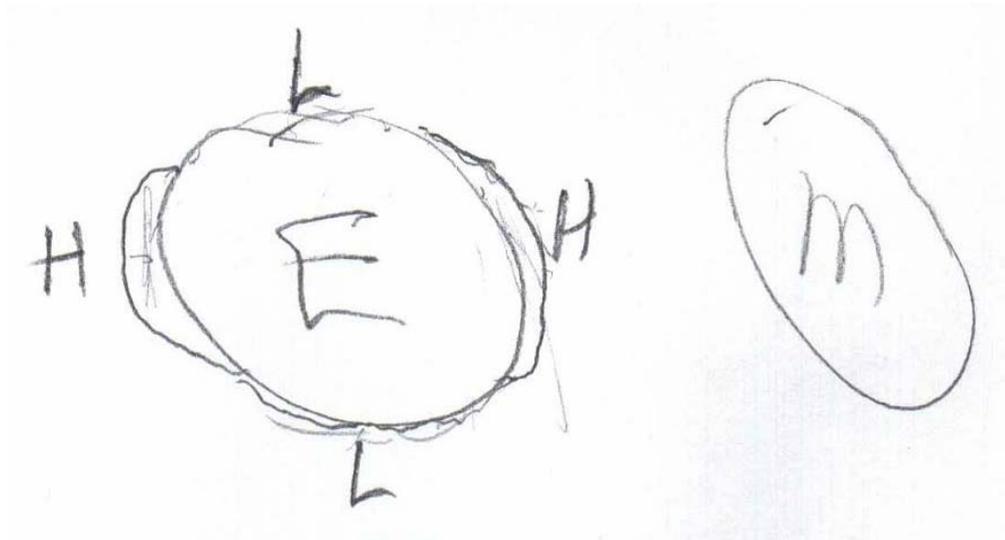


Figure 4.1: Participant 103's drawing of tides from an astronaut perspective.

Participant 103 demonstrated with his drawing and interview responses that he knew the two-tidal bulge model of the tides. One bulge was on the side of the Earth facing the moon and the other one on the side of the Earth farthest away from the moon. He specifically pointed out the two high tides and two low tides in his drawing. This represents a clear indication of the presence of a two-tidal bulge model in his explanation. He did not include the sun in his drawing but he demonstrated the role of the sun throughout the interview. The interview, which asked the participants to draw the Earth and bulges, was designed to find out whether participants could draw the two high and

two low tides on opposite sides of the Earth. Therefore, it cannot be determined whether or not the participant knew the role of the sun in generating the tides based on his drawing alone. The following excerpt from participant 103's post-interview responses provides a representative example of his understanding of the two-tidal bulge model and its causes.

Researcher: You probably have heard or seen that the water level on the ocean can (ebb and flood) rise and fall at certain times of the day. We call these events high tides and low tides. What do you think causes the high and low tides?

103: High tides are caused when the pull from the moon and the sun (**Sci\_GRA**) and the centrifugal forces (**Sci\_CENT**) that result are at its highest point throughout the day. And low tides are opposite of that when the moon is not at a point where a whole lot of gravitational force and the centrifugal force are not as great (*Participant was referring to the sides of the Earth where low tides occur.*)

Researcher: Could you tell me what high tides are?

103: The high tide is when the water is being pulled from the shores toward the moon due to gravitational forces.

Researcher: How many high tides do we have each day?

103: Two (**Sci\_TWO**).

Researcher: Can you show me high tides with the model?

103: Here (*Participant pointed to the two opposite sides of the Earth component which is closest to the moon component and farthest away from the moon component*). If this is where we're standing (*Participant pointed to a location in northern hemisphere of the Earth component, which is marked by researcher with a blue pin.*), this is the high tide (*Participant pointed to this location which is facing the moon component*). Right here (*Participant pointed to the side of the Earth component which is facing the moon component*) and right here (*Participant pointed to the side of the Earth component which is farthest away from the moon component*) (**Sci\_TWO**).

Participant 103 explained what caused the tides and showed the location of high tides on the Earth in relation to the moon and sun. This interview response provided another indication of his understanding of the two-tidal bulge model. Participant 103's

interview responses and the use of the model also indicated that he understood the cause of tides when he was asked about possible tides on the moon. His explanations for the causes of tides on the moon were also scientific and supported his two-tidal bulge model. The following excerpt from participant 103's post-interview responses provides a representative example of his understanding of tides on the moon.

Researcher: Suppose that the moon had an ocean and continents on it. Would there be tides on the moon?

103: Yes

Researcher: Why do you think so?

103: Because there would be a gravitational force between the Earth and the moon. So as the moon makes its rotation, the gravitational force would be different depending on relation of the Earth to the sun and to the moon (**Sci\_GRA**).

Researcher: Can you point out where tides would be on the moon?

103: Right here (*Participant pointed to the side of the moon component which is facing the Earth component*). It would be in the place where moon is facing the Earth. Kind of like the reverse of what happens with the moon how it pulls to the Earth. It would be the kind of same thing. The tide would be pulling strong right here (*Participant pointed to the side of the moon component facing the Earth component*).

Researcher: How many tides would there be on the moon?

103: There should be high tide high tide (*Participant pointed to the sides of the moon component which is closest to the Earth component and farthest from the Earth component*) and low tide and low tide (*Participant pointed to the sides of the moon component which were at right angles to the high tides. Those were the locations which were perpendicular to the imaginary line between the Earth and the moon*) (**Sci\_TWO**).

Researcher: Why do you think there would be high tides on the other side of the moon which is farthest away from the Earth?

103: Because of the centrifugal force (**Sci\_CENT**) just like with the Earth. As the moon spins, it causes centrifugal force that is the same as the gravitational pull.

After this participant was asked about the cause of the tides and the existence of the two-tidal bulge, the participant was asked the reason why tides occur twice a day in a location

on the Earth. The following excerpt from participant 103's post-interview responses provides a representative example of his understanding of high tides twice a day in the same place.

Researcher: Why do tides occur twice a day in the same place?

103: Because the Earth spins around itself (*Participant rotated the Earth component on its axis and held the moon component on the side of the Earth component*). If you look here (*Participant pointed to a place in northern hemisphere of the Earth component*), as the Earth comes around high tides right here (*Participant pointed to the sides of the Earth component facing the moon component and the side of the Earth component farthest away from the moon component*). You see high tides when the Earth makes one rotation in 24 hours so by the time it comes back you will see the tide again because the tides take 24 hours 50 minute. So you will see them twice (**Sci\_ROT**).

Participant 103's responses and use of the model indicated that because of the rotation of the Earth on its axis, we see two high tides in each day. Also, he indicated that the tidal cycle, the time between first and third high tide, is 24 hours 50 minutes. In the last part of the interview, the participants were asked to select a drawing from four options (See interview protocol, Appendix A) which symbolized an astronaut's view of the tides. An excerpt from the transcript where participant 103 made his selection follows:

Researcher: Which representation best symbolizes an astronaut's view of the Earth and tidal bulges?

103: A (*A is a scientific drawing of the two-tidal bulge model*) (**Sci\_TWO**)

Researcher: Why do you think it is A?

103: Because...if the astronaut looking at the Earth, um...The centrifugal force is causing a bulge on the one side (*participant pointed to one of the bulge on the drawing*) (**Sci\_CENT**) while gravitational pull of the moon causing on the other side (*participant pointed to other bulge on the drawing*) (**Sci\_GRA**). It just is causing the water to kind of bulge out in certain areas.

In summary, Participant 103's responses to the interview questions, his use of the models, and his drawings consistently demonstrated a scientific understanding of the two-tidal bulge model. The four critical points in understanding of tides were presented through his interview responses, through his use of the models, and through his drawings.

### *Scientific Fragments*

Participants' responses were categorized as scientific fragments if they included a subset of the scientific criteria but did not meet all four of the scientific criteria to explain tides, while showing no alternative conceptions. None of the participants held scientific fragments as their conceptual understandings before the instruction. However, three participants (115, 119, and 121) held scientific fragments as their types of conceptual understandings after instruction.

Participant 121's responses provide an example of a conceptual understanding which met three of the four scientific criteria, including that there are two high tides at the same time on the opposite sides of the Earth and two low tides also at the same time on the opposite sides of the Earth from each other (Sci\_TWO), gravitational forces from the sun and from the moon cause the tides (Sci\_GRA), and the rotation of the Earth on its axis is the reason why there are two high and two low tides in each day (Sci\_ROT). This participant did not include the fourth criteria, which was that centrifugal forces are created through the Earth's and the moon's rotation around a center of common mass, and these centrifugal forces are the main reason for the bulge which is on the side of the Earth farthest away from the moon (Sci\_CENT). Therefore, her responses indicated that

her conceptual understanding met the criteria for scientific fragments. The following excerpts from participant 121's post-interview responses and her use of the models provide a representative example of an understanding categorized as scientific fragments. Responses that were coded as scientific fragments are presented with the codes (Sci\_GRA, Sci\_ROT, or Sci\_TWO) listed in parentheses.

Researcher: Can you tell me what causes the tides?

121: Placement of the moon affects how high and how low a tide is. Based on where the moon is. If it is aligned up with the Earth and the sun then the tides are higher. If it is perpendicular 90 degrees, from the Earth and the sun, and then it is lower tide in general.

Researcher: Can you tell me a little bit more?

121: I know the sun plays a factor because of the gravitational pull (**Sci\_GRA**).

Researcher: Can you tell me a little bit more about the gravity? How does it affect the tides?

121: The pull. If the moon, Earth, and the sun are in a straight line, there are more gravitational pull (**Sci\_GRA**). I do not know how to explain.

Researcher: I have a model here you can use it for your explanations.

121: All are aligned like this (*Participant placed the sun component, the moon component, and the Earth component in a straight line*). There is a little pull on these two ends (*Participant pointed to the sides of the Earth component which were not facing the moon component and the Sun component. Those points were perpendicular to the straight line between sun-moon-Earth systems*). So Earth is spinning, there is this constant pull (*she pointed to the sides of the Earth component which was facing the moon component and the sun component*) as opposed to when the moon is here (*she placed the moon component at the third quarter moon phase position*), there is not as much pull because the sun is not much a factor (**Sci\_GRA**).

Researcher: What are causing the pulls on both sides of the Earth? What is pulling?

121: Well the gravity of the moon is mostly pulling the water out (**Sci\_GRA**). Water does not leave the Earth. Moon is pulling it.

Researcher: Imagine that you are an astronaut and traveling in a space rocket around the Earth. At some point you have looked at the Earth and you recognized the tides. From an astronaut perspective, draw what you would see of the Earth and label the picture with your explanation.

121: Looking down the Earth. Here is the Earth, here is the moon, and here is the sun (*Participant's drawing presented in Figure 4.2*). I guess the tides would be pulling like this (*she pointed to the bulges one was closer to the sun and the other one was closer to the Moon on her drawing*) (**Sci\_TWO**).

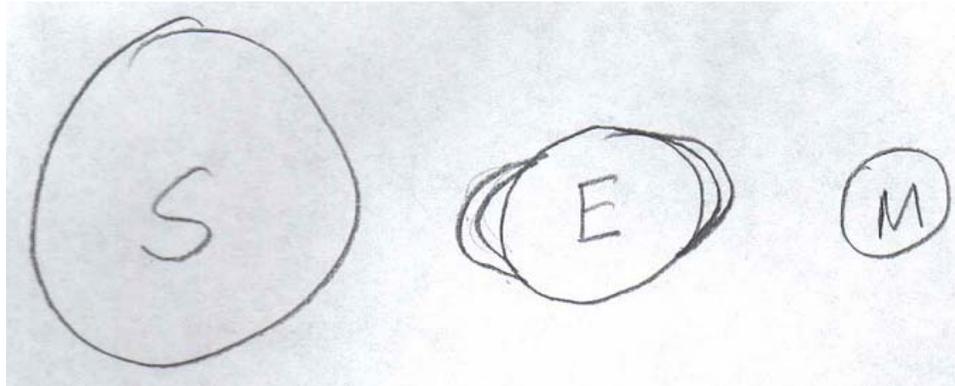


Figure 4.2: Participant 121's drawing of tides from an astronaut perspective.

Researcher: Can you tell me a little bit about your drawing?

121: What I show was the sun, Earth, and moon are in a straight line so tides being pulled higher tide so these rings represent the tide being higher or the water being pulled a little bit more.

Researcher: Suppose that the moon had an ocean and continent on it. Would there be tides on the moon?

121: Yes

Researcher: Why do you think so?

121: Because the moon and the Earth share gravitational pull of each other. So the Earth's gravitational pull have the same effect on the moon as the moon on the Earth (**Sci\_GRA**).

Researcher: If it is high tide on one side of the Earth which is facing the moon, what is happening on the other side of the Earth which is not facing the moon?

121: It is also high tide (**Sci\_TWO**).

Researcher: Why do tides occur twice a day in the same place?

121: Because the Earth's rotation (**Sci\_ROT**). It is spinning in 24 hours a day. So when it makes one half of the rotation it is the other half point.

Researcher: Which representation (See Appendix A) best symbolizes the astronaut view of the Earth and tidal bulges?

121: A (*A is a scientific drawing of two bulge model*) (**Sci\_TWO**).

Researcher: Why do you think it is A?

121: Because since there are two high tides during the day they are 12 hours apart about. This would show that both sides of the Earth are having the tidal bulges. They are opposite sides of the Earth (**Sci\_TWO**).

In summary, Participant 121's responses to the interview questions, use of the models, and her drawings (Figure 4.2) showed a type of understanding which was categorized as scientific fragments. In her drawing, she provided evidence that she knew the two-tidal bulge model. A subset of the four critical points for understanding of tides were presented through her interview responses, through her use of the model, and through her drawings without showing any indication of alternative conception.

#### *Scientific Fragments with Alternative Fragment*

Participant responses that included a subset but not all of the four scientific criteria and included an alternative conception to explain tides were categorized as the scientific fragments with alternative fragment type. None of the participants held an understanding that was categorized as scientific fragments with alternative fragment as their conceptual understandings before the instruction. Six participants (numbers 108, 110, 118, 123, 124, and 125) provided responses that met a subset of the four scientific criteria after the instruction and they also indicated the rotation of the moon around the Earth during one 24-hour period causes the tides to move with moon (**Alt\_MOON**). The following excerpts from participant 108's post-interview responses provided a

representative example of an understanding categorized as Scientific Fragments with Alternative Fragment.

Researcher: Can you tell me what you know about the tides in general?

108: I know they are caused by high tides are caused by the pull of the moon and the sun (**Sci\_GRA**) the centrifugal force of the moon rotating around the Earth (**Sci\_CENT**). And the high tides occur twice a day and low tides occur twice a day in the same location.

Researcher: What do you think causes the tides?

108: Gravitational pull of the moon on the Earth (**Sci\_GRA**) and the centrifugal force (**Sci\_CENT**) of the moon rotating around the Earth. So when the moon is aligned...when the Earth is here and when the moon is here (*Participant placed the sun, the Earth, and the moon components in a straight line*), the water is pulling toward the moon because of gravitational force towards the moon (**Sci\_GRA**) and away from the moon because of the centrifugal force (**Sci\_CENT**). And as the moon rotates around the Earth, the pull moves as well (*Participant rotated the moon component around the Earth component*) (**Alt\_MOON**).

Participant 108 indicated that the gravitational forces and centrifugal forces are the forces which cause the tides. In addition, her response gave the indication that she held an alternative conception about the rotation of the moon around the Earth during one 24-hour period causing the tides to move with the moon (**Alt\_MOON**). Based on only this statement, it cannot be concluded that she held a moon orbit related alternative conception; however, her responses to other question presented in the following section of the interview provide evidence that she held the moon orbit related alternative conception.

Researcher: Why do tides occur twice a day in the same place?

108: Because a lunar day is 24 hours and 50 minutes which is almost a day on Earth... and the moon rotates around the Earth. It would be...um. Ok here on this place high tide (*Participant pointed to the blue pin which was facing the moon-blue pin positioned by the researcher previously*) and it comes around here (*Participant revolved the moon component around the Earth component and*

*brought it to the side opposite the blue pin) 12 hours 25 minutes earlier, there would be another tide (participant 108 revolved the moon component around the Earth component) (Alt\_MOON).*

Researcher: You are saying that the moon rotate around the Earth in every 24 hours and 50 minutes.

108: Yes. I think so.

In the following sections of the interview, participant 108's interview response provided evidence that she held the two-tidal bulge model which is caused by gravitational forces and centrifugal forces.

Researcher: Could you tell me what high tides are?

108: This is the moon and this is the Earth and this is the sun (*Participant placed the Earth component between the moon component and the sun component in a straight line*). The high tide is at the blue pin (*Blue pin was facing the sun. A small blue pin is placed by the researcher to mark a certain location on Earth*) and on the other side of the Earth facing the moon (**Sci\_TWO**). The high tides are caused by the gravitational pull (**Sci\_GRA**) and centrifugal force (**Sci\_CENT**). Gravitational pull of the moon and the sun, mostly the moon, the centrifugal force of the moon and the sun mostly the moon.

Researcher: Which representation (See interview protocol in Appendix A) best symbolizes the astronaut view of the Earth and tidal bulges?

108: A (*A is a scientific drawing of two-tidal bulge model*) (**Sci\_TWO**).

Researcher: Why do you think it is A?

108: Because it is showing the pull of the water from the gravitational force (*she pointed to one of the bulges on the drawing*) and pull of the water from the centrifugal force (*she pointed other bulge on the drawing*) (**Sci\_TWO**).

Participant 108's responses indicated that she had a subset of scientific criteria which were: centrifugal forces created by the rotation of the Earth and the moon around a center of common mass are the main reason for the bulge on the side of the Earth farthest away from the Moon (**Sci\_CENT**), gravitational forces from the sun and from the moon cause the tides (**Sci\_GRA**), and there are two high tides at the same time on opposite

sides of the Earth and two low tides also at the same time on the opposite sides of the Earth from each other (Sci\_TWO). Her responses did not include the conception that the rotation of the Earth on its axis is the reason why we have two high and two low tides in each day. In addition to three scientific criteria, she held an alternative conception which was that the rotation of the moon around the Earth during one 24-hour period causes the tides to move with the moon (Alt\_MOON). In addition, she confused the high and low tides with the spring and neap tides. Confusion of high tides with spring tides and neap tides with low tide was common among the participants who held scientific fragments with alternative fragment as his/her type of conceptual understanding.

### *Alternative*

Alternative conceptions, as used here, are the conceptual models that are different than the scientific models (Vosniadou, 1991), and are obtained through a learner's everyday experiences intuitively or when their intuitive conceptions conflict with scientific conceptions (Vosniadou & Brewer, 1992). Analyses of pre-interview responses indicated that none of the participants held conceptual understandings that were categorized as a scientific understanding, scientific fragments, and scientific fragments with alternative fragment before the instruction. Rather, all of the participants' understandings were categorized either as alternative or alternative fragments before the instruction.

Among the thirty participants who completed the pre-interview, eleven or 37 % of the participants' (102, 106, 107, 109, 117, 122, 123, 124, 125, 126, and 128) conceptual

understandings were categorized as alternative conceptual understanding before the instruction. Participants identified as having alternative conceptual understanding indicated that the occurrence of tides is related to the time of day and appearance of the sun and the moon in the sky (Alt\_TIME); that the gravitational pull of the moon causes water to pile up on one side of the Earth and recedes on the other side (Alt\_GRAVITY); that the rotation of the moon around the Earth during one 24-hour period causes the tides to move with the moon (Alt\_MOON); or that tides are caused by rain, wind, Earthquakes, or the movement of the ocean (Alt\_OTHER). All of these four alternative conceptions or a subset of these conceptions were applied to justify a one-tidal bulge model by the participants. Even if these alternative conceptions included small scientific pieces of information, these small scientific pieces of information did not provide enough coherence to explain a two-tidal bulge model. In the following section, each one of the alternative conceptions which was identified is explained in detail with supporting excerpts from the interviews.

#### *Alternative Gravity (Alt\_GRAVITY)*

Based on their interview responses, use of models, and their drawings, some preservice teachers indicated that there was a one-tidal bulge on Earth because of the gravitational pull of the moon on the Earth. They indicated that the gravitational pull of the moon was the only tide-generating force, and ignored the other main tide-generating force, centrifugal force. The gravitational pull of the moon is a scientific concept in

explaining the tides, but when gravitational pull is perceived as the only reason for the generation of tides, an alternative conception of tides emerges.

The preservice teachers expressed the view that because the gravitation pull of the moon as the only tide-generating force, water is piled up on the side of the Earth which is facing the moon and recedes on the side of the Earth which is farthest away from the moon. The following excerpt from participant 114's pre-interview responses provides a representative example of an alternative conception of the one tidal bulge generated by the gravitational pull of the moon.

Researcher: If it is high tide on one side of the Earth, which is facing the moon, what is happening on the other side of the Earth which is not facing the moon?

114: I would assume low tide.

Researcher: Why do you think it is low tide?

114: I would think that if it is high tide, then the water is being shifted. I guess for like a better word that...can I use the model...so the moon is over here (*Participant placed the Earth component and the moon component side by side on the table*) and this is the high tide over here (*Participant pointed to the side of the Earth facing the moon*), I would say on this side (*Participant pointed to the side of the Earth which is farthest away from the moon*) it is low tide because all the water is being like kind of shifted I guess to over here (*Participant pointed to the side of the Earth component which was facing the moon component*). So, that is high tide over here (*Participant pointed to the side of the Earth component facing the moon component*) and the water is receding on this side (*Participant pointed to the side of the Earth component farthest away from the moon component*) that would be low tide over here (**Alt\_GRA**).

It seems that participant 114 had a model where ocean water piles up on the side of the Earth which is facing the moon and recedes on the other side of the Earth which is farthest away from the moon due to the gravitational pull of the moon. Without adding

the other tide generating force, this model is an alternative model by itself because it includes only one tidal bulge.

One of the main features of a gravitational force is the inverse relationship between the gravitational force and the distance between the objects. Participants applied this knowledge when they explained the tides with the gravitational pull of the moon. The following excerpt from participant 110's pre-interview responses provides a representative example of participant 110's understanding of the gravity and distance relationship.

Researcher: You probably have heard or seen that the water level on the ocean can (ebb and flood) rise and fall at certain times of the day. We call these events high tides and low tides. What do you think causes the high and low tides?

110: Just like I said the distance of the moon from the Earth, like when the moon is closer to the Earth during one of the day that would be high tide. When the gravity is stronger, that would be high tide and then it is farther away, it is low tide (**Alt\_GRA**).

Participant 110 included the relationship to the distance between the moon and the Earth and strength of the gravitational pull in the interview response. When participants mentioned the distance between the moon and the Earth they explained that they meant the moon was directly over a specific location on the Earth. In other words, a certain location on the Earth is directly facing the moon. When participants talked about the moon being farthest away, they meant that the moon was facing the other side of the Earth. The following excerpt from participant 103's interview responses and use of model provides a representative example of that notion.

Researcher: You probably have heard or seen that the water level on the ocean can (ebb and flood) rise and fall at certain times of the day. We call

these events high tides and low tides. What do you think causes the high and low tides?

103: The Earth is moving at a somewhat faster orbit than the moon. As it goes around I think that the orbit of the moon is not like a perfect circle so that at certain points throughout the day like right here (*Participant pointed to a location on the northern hemisphere of the Earth component*) and I think the pull of the moon is a lot stronger right here (*Participant pointed to the location on the Earth component which was facing the moon component*) because we are facing it. As we turn (*Participant rotated the Earth component on its axis*), the moon does not turn as much. I think the moon's pull gets weaker and weaker (*Participant rotated the Earth component and her location on Earth component moved toward the side of the Earth which was not facing the moon*) than throughout the day it gets stronger and stronger (*Participant rotated the Earth component and her location on the Earth moved toward the side of the Earth which was facing the moon*) and get back to that point (**Alt\_GRA**).

In summary, gravity is the main concept linked to tides that most participants reported as having previous instruction about. Participants usually knew that there was a gravitational attraction between the Earth and the moon. Participants' conception of gravity as a tide generating force dominated the other tide-generating forces in the pre-instruction. Participants who stated that only the gravity of the moon caused the tide had a one-tidal bulge model of the tides, and they explained the one-tidal bulge with the gravitational pull of the moon. The moon's gravity explained only one bulge in the participants' models of tides.

#### *Alternative Time of Day (Alt\_TIME)*

Based upon their interview responses and use of the models, some preservice teachers expressed the view that the occurrence of tides was related to the time of day and the appearance of the sun and the moon in the sky. Participants who stated that the

different tides occurred at specific times of the day stated their ideas by directly saying tides are related to morning or afternoon, day or night, or appearance of the sun and the moon. For example, they indicated that high tides happen at night when you see the moon and low tides happen during the day when you see the sun. Participant 114's interview responses provide a representative example of this type of alternative conception.

Participant 114's responses indicated that she had an explanation with an emphasis on the time of day for the causes of tides.

Researcher: You probably have heard or seen that the water level on the ocean can ebb and flood, or rise and fall at certain times of the day. We call these events high tides and low tides. What do you think causes the high and low tides?

114: I know that high tide occurs later in the day like the low tide is in the morning and as the afternoon goes on as the day gets later, tides become higher (**Alt\_TIME**). What causes that? I do not know but I could guess. Like I said as the day gets later, the tides change. The tide gets higher. So maybe it has something to do with either how the Earth is rotating or maybe how the position where the sun and moon are because like as I said, when the day goes on tides change (**Alt\_TIME**). So either the position of the Earth in the way that is rotating or maybe where the position of the moon and the sun are.

Based on her interview response, participant 114 expressed the view that the time of day plays a role in the cause of the tides. She included in her explanations about the occurrence of the tides during different times of the day. She also consistently included that low tides occur in the morning and high tides occur in the afternoon.

Participants not only related the tides to the morning or afternoon, but also they related them to the appearance of the moon and the sun. The connection between the appearance of the moon and the sun in the sky and the causes of tides can be seen in participant 106's pre-interview responses, which indicated that during the night, the

moon is up and during the day, the moon is not up. Thus, when it is night, and when the moon is out we have high tides. In the following parts of the interview she explained these ideas. An excerpt from participant 106's interview response follows:

Researcher: You probably have heard or seen that the water level on the ocean can (ebb and flood) rise and fall at certain times of the day. We call these events high tides and low tides. What do you think causes the high and low tides?

106: I am going to go with the moon just because I know that the lower the tide is the closer to the moon. As the lower tides happen during the afternoon to evening and when the moon is usually coming out depending...usually moon is out when you have a low tide (**Alt\_TIME**). Actually you see it.

The moon's appearance in the sky and the sun's appearance in the sky were related to the high and low tides by some participants. Participants usually indicated that the moon comes out during the night and the sun comes out during the day because of the Earth's rotation and the appearance of these two celestial bodies causes the tides. The following excerpt from participant 115's pre-interview responses provides an example of how some participants related the appearance of the moon and the sun with tides.

Researcher: You probably have heard or seen that the water level on the ocean can (ebb and flood) rise and fall at certain times of the day. We call these events high tides and low tides. What do you think causes the high and low tides?

115: I guess at mid day it is really high tide I think. Maybe it has something to do with the sun's being out and then at night also maybe the moon has something to do with the high tide (**Alt\_TIME**). So come in mid day high tide and then get low again and come in again midnight.

The idea that the tides occur based on the time of day or appearance of the sun during the day or the moon during the night were presented when participants were asked about the bulge which is on the side of the Earth furthest away from the moon. The

following excerpt from participant 115's interview responses provides a representative example of an answer to this question.

Researcher: If it is high tide on the side of the Earth, which is facing the moon, what is happening on the other side of the Earth which is not facing the moon?

106: That would be a low tide

Researcher: Why do you think that would be low tide?

106: Because high tide and low tide correlate with the day and night (**Alt\_TIME**). We see opposite times of the day another side of the Earth.

Participants also related the high and low tides with the day and night in a way that during a 24-hour period there is one night and one day similarly there should be one high tide and one low tide during that 24-hour period. The excerpt from participant 102's interview responses indicated how this connection between the day and night and the tides was made.

Researcher: If it is high tide on the side of the Earth, which is facing the moon, what is happening on the other side of the Earth which is not facing the moon?

102: Logically low tide

Researcher: Why do you think low tide?

102: Because it only happens once a day and we rotate once a day we have night and day (**Alt\_TIME**).

It seems that participant 102 tried to make a connection between the tides and the rotation of the Earth by saying that the Earth rotates once a day and as a result we have one low tide and one high tide related to day and night. In other words, the participant made connections between the events which occur daily. For instance, the sun rises and sets once a day, the moon shows itself once a day, the Earth makes a full rotation once a day. Based on the interview responses, if there is a high tide on the side of the Earth facing the moon, there should be a low tide on the opposite side of the Earth farthest

away from the moon similar to when one side of the Earth is having day and the other side of the Earth has night. During the Earth's rotation, a certain location on the Earth faces the moon just once in a day. Therefore, this participant used the logic that the location which faces the moon experiences one high tide in a day.

In summary, some preservice teachers expressed the view that the occurrences of tides are dependent on the time of day. Based on the interview responses, the use of the models, and their drawings, they seemed to perceive that tides happen because it is morning or afternoon or because the sun or the moon is up in the sky.

#### *Alternative Moon (Alt\_MOON)*

Based on their interview responses, use of models, and their drawings, some preservice teachers expressed the view that different parts of the Earth have one tidal bulge at different times of the day because of the moon's rotation around the Earth. In reality, as a result of the rotation of the Earth on its axis, we experience two high and two low tides in each day on Earth. With this model, participants indicated that the moon rotates around the Earth once a day. The following excerpt from participant 113's pre-interview response shows how this participant described the relationship between the moon and the tides.

Researcher: Could you tell me what high tide is?

113: It is whatever side of the moon. Oh men!

Researcher: Could you tell me a little more?

113: I am trying to figure out how to do it. Right now this is high tide here (*Participant pointed to the side of the Earth component which was facing the moon component*). As the moon moves, it is becoming... it is pulling the tide with it. This way so this was the high tide as the moon is moving. It is moving toward low tide because this moon is

dragging all its water with it. So it is becoming a high tide over here now it is high tide over here (*Participant pointed to the side of the Earth component which was facing the moon component*). And as it is continuous to move, is pulling the water back with it. So it is becoming low tide over here (*Participant pointed to the side of the Earth component farthest away from the moon component*) and now high tide over here (*Participant pointed to the side of the Earth component which was facing the moon component*) I guess. So high tide is wherever the moon is closest to because it can pull its gravity is stronger here because its proximity is closer here than it is over here. and then it is also why tides goes at a regular schedule because this is a fixed orbit like we know day is 24 hours so moon takes that long to move around the Earth (**Alt\_MOON**).

Based on the participant 113's interview responses and use of the model, the rotation of the moon around the Earth causes the tides to change location throughout one day. Participant 113 demonstrated with the model that the side of the Earth which is facing the moon would be having high tide and the other side of the Earth which is farther away from the moon would be having low tide as was demonstrated by revolving the moon component around the Earth component. In other words, when the moon is changing its relative position around the Earth, the location of the tides change. However, in contrast to participant 113's understanding, the moon does not revolve around the Earth as fast as the participant demonstrated. In reality, the moon completes its orbit around the Earth in almost 30 days, but participant 113's model showed that the moon rotating around the Earth in 24 hours. The following excerpts from participant 118's and participant 125's interview responses also provides a representative example of this alternative conception.

Researcher: Why tides occur twice a day in the same place?

118: Because moon is constantly moving and we talked about the day and like moon would be like 12 hours and....what is it 24 hours and 50 minutes? So it rotates the Earth twice and I guess in one day.

Which sounds weird but it does yes. I guess it rotates the Earth twice in one day (**Alt\_MOON**).

Researcher: Why tides occurs twice a day in the same place.

125: Because the moon takes 24 hours to get around so half around is 12 hours. When it is here one high tide (*Participant pointed to the side of the Earth component which is facing the moon component*) and back here high tide (*Participant pointed to the side of the Earth component which is facing the moon component*). So, two times a day (**Alt\_MOON**).

The preexisting knowledge about the moon for participants 118 and 125 indicated that tides are caused by the moon and move with the moon within a 24 hour period.

Based on their use of the model and interview responses, wherever the moon is facing the Earth, there is one tidal bulge on the same side of the Earth as the moon and this bulge moves with the moon.

The idea that the one-tidal bulge model is caused by the moon was also evident in other sections of the some participants' interview responses. The perception of the relationship between the moon and tides also was revealed when participants were asked whether or not there would be tides on the moon if the moon had oceans and continents on it. Participant 114's interview responses provide a representative example of the information obtained from this question.

Researcher: Suppose that the moon had oceans and continents on it. Would there be tides on the moon?

114: I am going to say no.

Researcher: Why do you think no?

114: Like I said before, I do not know this but I think I heard that tides are caused by the moon, the phases of the moon, and the position of the moon. So, if there were actual ocean and continents on the moon, I do not think there would be anything to affect the moon because there is not anything that orbits the moon (**Alt\_MOON**). The moon orbits the Earth but nothing orbits the moon. I do not think there would be anything that affects what is on the moon.

Participant 114's interview responses indicated that the main cause of the tides was attributed to the moon itself. Participant 114's responses indicated there would not be tides on the moon because the moon does not have its own moon. Earlier this participant mentioned the effects of the moon on the Earth, but the responses did not include the reciprocal gravitational relationship between the Earth and the moon. This explanation provides evidence that this participant did not give credit to the gravitational forces between the moon and the Earth in explanation of the causes of tides. Ignoring the reciprocal gravity between the Earth and moon brings out another perception that from the Earth perspective, the moon affects the Earth tides, but from the moon perspective the Earth would not affect the moon tides. In addition, this participant's explanation indicated that the sun's influence on the tides was ignored. In reality even if the moon does not have its own moon, the sun would still be a cause of the tides on the moon.

*Alternative Other (Alt\_OTHER)*

Based on their interview responses and use of the models, some preservice teachers' interview responses, and drawings indicated that tides are caused by factors related to atmospheric or environmental factors such as wind, rain, Earthquakes, and movement in the water. Some participants tried to explain tides and the causes of tides without including the Earth, the moon, or the sun in their explanations. Excerpts from participant 126's interview responses provide a representative example of an alternative conception related to environmental factors. Participant 126 explained tides as mainly being caused by Earthquakes and weather patterns.

Researcher: Could you tell me what you know about tides?  
 126: Well. I know that it is when the water from the ocean goes in and out along the shore. I know that there is some, um, I do not know whether it is theory or how much it is facts that like the Earthquake like under the ocean force them and it causes tides. Bigger tides in the water pull backward (**Alt\_OTHER**).

Researcher: What do you think causes tides other than the Earthquakes?  
 126: Not really sure maybe the weather patterns. Oh maybe the moon phases.

Researcher: Maybe the weather patterns and moon phases?  
 126: Yes

Researcher: Can you tell me little more about weather patterns and moon phases. How they are related to tides?  
 126: I am just thinking maybe weather pattern has something to do with like I do not know sometimes when it is windy it is like tides are moving a little bit faster (**Alt\_OTHER**). Or it could be just my imagination. But maybe I am not quite sure. Moon phases. I do not really know. I just know I heard it somewhere. Maybe the way the Earth is rotating may affected. I do not know.

Some participants stated that tides are caused by any kind of movement in the ocean or by the weather. For this alternative conception participants confused the tides with the ocean waves which are caused by movement in the ocean and weather. Excerpts from participant 119's interview responses provide a representative example of an alternative conception related to environmental factors.

Researcher: You probably have heard or seen that the water level can ebb and flood at certain times of the day. We call these events high tide and low tide. What do you think causes high and low tides?  
 119: I think the weather. I think weather. When it is very calm and there is no rain outside, you may get little low tides little sweep of the water coming up on the beach. But if it is very windy or maybe stormy outside you get high tide (**Alt\_OTHER**). Because that is why they warn you stay off the beach.

Researcher: Two times a month we have what we called spring tides. These are the times when the high tides are very high and low tides are very low. What do you think causes spring tides?  
 119: It is called spring tide?

Researcher: Yes

119: I am not sure it could be the weather. It could be the activity on the water from the animals or it just could be the changes of the level of sand that could change.

Researcher: How does animal movement affect the tides?

119: Animal. Because they affect the gravel or the sand. I know in the Red sea you can actually see the bottom of the Red sea. You can see the bottom of the sea you can see like sea urchins, octopus, craw fish, some other strange looking fish but they bury themselves in the bottom of the sea. I think the shift of land under there definitely affects how the tide would change (**Alt\_OTHER**).

The perceived relationship between weather and tides was also presented in the drawings by the same participant. For example, participant 126 drew a cyclone when asked to draw the tides from an astronaut perspective. Depicted in Figure 4.3, her drawing was like a growing circle similar to images seen in weather reports. An excerpt from her interview transcript, where she explained and discussed her drawing, follows.

Researcher: Can you tell me about your drawing?

126: I am just thinking when you see satellite pictures you would see like countries and where the oceans are. You see like y shapes. You know what I mean weather.... like hurricanes. They like ... (*she pointed to her drawing*)

Researcher: So these are the images on the weather channels.

126: Yes

Participant 126's responses and drawing indicated that she explained the cause of tides with the weather patterns. In reality, weather is one of the main reasons for the development of the waves in the ocean. Therefore, the participant 126 deemed it as likely that waves and tides are correlated.



Figure 4.3: Participant 126's drawing of tides from an astronaut perspective.

In summary, interview responses and drawings indicated that some participants related the tides to the movement in the ocean, such as Earthquakes, tsunamis, and with atmospheric events, such as wind and rain. However, these explanations did not include the effects of the moon, sun, and the Earth as causes of the tides. Therefore, these explanations were coded as alternative conceptions.

#### *Alternative Fragments*

Participants' responses which included a subset or subsets of alternative conceptions and did not express a complete model to explain tides were coded as alternative fragments as the type of conceptual understanding. This type of conceptual understanding was the most common among the preservice teachers before the instruction. Before the instruction, 19 of the 30 participants (103, 104, 105, 108, 110,

111, 112, 113, 114, 115, 116, 118, 119, 120, 121, 127, 129, 130, and 131) held alternative fragments for his/her type of conceptual understanding. None of the participants held alternative fragments as his/her conceptual understanding after the instruction.

### *Findings for Before and After Instruction*

In this section, findings are presented in response to Research Question 2 and Research Question 3. Participants' conceptual understandings of tides were investigated separately before the instruction and after the instruction for each research question.

#### *Before Instruction*

***Research Question 2: What are the conceptual understandings held by preservice teachers about tides before completing an inquiry-based technology-enhanced instruction including the study of tides?***

**Before the instruction on tides, preservice teachers were likely to hold an alternative conceptual understanding of tides.** The thirty preservice teachers who participated in the study were interviewed before the instructional intervention on tides. Frequencies and percentages before the instruction are summarized in Table 4.1 for the 30 participants. Categorizations of their types of conceptual understandings before the instruction are listed by participant in Table 4.2.

Type of Conceptual Understanding	Before Instruction (n=30)		Before Instruction (n=19) Sub-group of 30 participants	
	Frequency	Percentage	Frequency	Percentage
Scientific	0	0	0	0
Scientific Fragments	0	0	0	0
Scientific Fragments with Alternative	0	0	0	0
Alternative	11	37 %	5	26 %
Alternative Fragments	19	63 %	14	74 %
None	0	0	0	0

Table 4.1: Frequency of type of conceptual understanding before instruction on tides

Participant #	Type of Conceptual Understanding Before Instruction (n=30)
102*	Alternative
103*	Alternative Fragments
104*	Alternative Fragments
105	Alternative Fragments
106	Alternative
107	Alternative
108*	Alternative Fragments
109	Alternative
110*	Alternative Fragments
111*	Alternative Fragments
112	Alternative Fragments
113	Alternative Fragments
114*	Alternative Fragments
115*	Alternative Fragments
116*	Alternative Fragments
117	Alternative
118*	Alternative Fragments
119*	Alternative Fragments
120*	Alternative Fragments
121*	Alternative Fragments
122	Alternative
123*	Alternative
124*	Alternative
125*	Alternative
126*	Alternative
127*	Alternative Fragments
128	Alternative
129*	Alternative Fragments
130	Alternative Fragments
131	Alternative Fragments

\* These are the, n=19, sub-sample of 30 participants.

Table 4.2: Results by the participants' type of conceptual understanding before the instruction on tides

Before the instruction none of the 30 preservice teachers held scientific, scientific fragments, or scientific fragments with alternative fragment as his/her type of conceptual understanding. Also, none of the participants held a two-tidal bulge model before the instruction. Eleven of the 30 participants, or 37 %, held alternative conceptual understandings and 19 of the 30 participants, or 63 %, held alternative fragments as his/her type of conceptual understanding.

**Preservice teachers who held alternative conceptions about tides were likely to indicate that there is one tidal bulge on Earth, and they tried to explain this one-tidal bulge model through the use of various alternative conceptions.** The most common alternative conception was that the moon causes one tidal bulge and the rotation of the moon around the Earth during one 24-hour period causes the tides to move in relation to the movement of the moon. The second most common alternative conception was that the gravity of the moon causes the water to pile up on one side of the Earth while the water recedes on the other side of the Earth. The third most common alternative conception was that the occurrence of tides is related to the time of day and appearance of the sun and the moon in the sky. A small group of people had the alternative conception that the tides are caused by rain, wind, and Earthquakes. These participants did not mention the Earth, moon, sun, gravity, or rotation of the moon and the Earth in their explanations of tides.

*After Instruction*

***Research Question 3: What are the conceptual understandings held by preservice teachers about tides after completing an inquiry-based technology-enhanced instruction including the study of the tides?***

Nineteen participants, who previously participated in the pre-instruction interview, volunteered to complete the instruction which began shortly after the pre-instruction interviews. After the instruction, all 19 of the participants were interviewed again and 18 of these participants completed the post-test. The findings from the post-interview are summarized in Table 4.3, which displays the frequency of type of conceptual understanding after the instruction. The categorization of each participant's type of conceptual understanding is presented in Table 4.4.

Type of Conceptual Understanding	After instruction (n=19)	
	Frequency	Percentages
Scientific	10	52 %
Scientific Fragments	3	16 %
Scientific Fragments with Alternative	6	32 %
Alternative	0	0
Alternative Fragments	0	0

Table 4.3: Frequency of type of conceptual understanding after the instruction

Participant #	Type of Conceptual Understanding
102	Scientific
103	Scientific
104	Scientific
108	Scientific Fragments with Alternative
110	Scientific Fragments with Alternative
111	Scientific
114	Scientific
115	Scientific Fragments
116	Scientific
118	Scientific Fragments with Alternative
119	Scientific Fragments
120	Scientific
121	Scientific Fragments
123	Scientific Fragments with Alternative
124	Scientific Fragments with Alternative
125	Scientific Fragments with Alternative
126	Scientific
127	Scientific
129	Scientific

Table 4.4: Results by the type of conceptual understanding by participant after the instruction on tides

**After completing an inquiry-based and technology-enhanced instruction on the tides, preservice teachers were likely to hold a scientific conceptual understanding.** After the instruction on tides, 10 of the 19 participants (52 %) held a scientific conceptual understanding, and three of the participants (16%) held scientific fragments as his/her type of conceptual understanding. Six of the participants (or 32 %)

held scientific fragments with an alternative fragment as his/her type of conceptual understanding. None of the participants held alternative or alternative fragments as his/her type of conceptual understanding after the instruction.

### *Changes in Conceptual Understanding*

In this section, the results are presented in response to Research Question 4. Participants' types of conceptual understandings about tides before the instruction were compared to their types of conceptual understandings after the instruction in order to investigate the conceptual change process and the effects of the instructional intervention.

***Research Question 4: How do preservice teachers' types of conceptual understandings of tides differ after completing an inquiry-based technology-enhanced instruction including the study of tides?***

The frequency and percentage of participants' types of conceptual understandings before and after the instruction for each type of conception are presented in Table 4.5. The categorization of the participants' types of conceptual understandings is listed by participant in Table 4.6, which displays the type of conceptual understanding before and after the instruction for the 19 participants who received instruction.

Type of Conceptual Understanding	<u>Before instruction</u>		<u>After instruction</u>	
	Frequency	%	Frequency	%
Scientific	0	0	10	52 %
Scientific Fragments	0	0	3	16 %
Scientific Fragments with Alternative	0	0	6	32 %
Alternative	5	26 %	0	0
Alternative Fragments	14	74 %	0	0

n=19

Table 4.5: Frequency and percentage for type of conceptual understanding held by participants before and after the instruction

ID #	Type of CU- Before Instruction	Notes Conceptual code	Type of CU- After Instruction	Notes Conceptual code
102	Alt	Alt_MOON, Alt_TIME, Alt_OTHER,	Scien	
103	AltFrag	Alt_GRA, Alt_MOON,	Scien	
104	AltFrag	Alt_GRA, Alt_MOON,	Scien	
108	AltFrag	Alt_GRA, Alt_MOON,	ScienFragAlt	Alt_MOON
110	AltFrag	Alt_GRA	ScienFragAlt	Alt_MOON
111	AltFrag	Alt_GRA, Alt_MOON,	Scien	
114	AltFrag	Alt_MOON, Alt_TIME,	Scien	
115	AltFrag	Alt_MOON, Alt_TIME,	ScienFrag	
116	AltFrag	Alt_MOON, Alt_TIME,	Scien	
118	AltFrag	Alt_GRA, Alt_MOON,	ScienFragAlt	Alt_MOON
119	AltFrag	Alt_OTHER	ScienFrag	
120	AltFrag	Alt_OTHER	Scien	
121	AltFrag	Alt_GRA, Alt_MOON,	ScienFrag	
123	Alt	Alt_GRA, Alt_MOON, Alt_TIME,	ScienFragAlt	Alt_MOON
124	Alt	Alt_GRA, Alt_MOON, Alt_TIME,	ScienFragAlt	Alt_MOON
125	Alt	Alt_MOON, Alt_TIME, Alt_OTHER,	ScienFragAlt	Alt_MOON
126	Alt	Alt_MOON, Alt_TIME, Alt_OTHER,	Scien	
127	AltFrag	Alt_GRA, Alt_TIME,	Scien	
129	AltFrag	Alt_GRA, Alt_MOON,	Scien	

Note: CU=Conceptual understanding, Alt: Alternative, AltFrag: Alternative Fragments, Scien: Scientific, ScienFrag: Scientific Fragments, ScienFragAlt: Scientific Fragments with Alternative Fragment.

Table 4.6: Type of conceptual understanding of tides before and after instruction

**Overall, the types of conceptual understandings by participants changed from mostly alternative and alternative fragments before the instruction to mostly scientific and scientific fragments after the instruction.** Findings of the type of conceptual understanding before the instruction revealed that all of the participants who completed the instruction held an alternative conceptual understanding (5 of 19, or 26 %) or alternative fragments (15 of 19, or 74 %) as his/her type of conceptual understanding before the instruction. After the instruction, more than half (10 of 19, or 52 %) held a scientific understanding or scientific fragments (3 of 19, or 16%) as his/her type of conceptual understanding.

**After completing an inquiry-based and technology-enhanced instruction which included the study of tides, some preservice teachers continued to hold their moon-orbit-related alternative conception.** Participants (108, 118, 123, 124 , and 125) who held the alternative conception that the moon causes a one-tidal bulge and the rotation of the moon around the Earth causes the tides to move with the moon during one 24-hour period (Alt\_MOON), retained that conception after the instruction.

**After completing an inquiry-based and technology-enhanced instruction which included the study of tides, preservice teachers who held scientific fragments as his/her type of conceptual understanding were also likely to include alternative fragments.** Six of the nine participants (number 108, 110, 118, 123, 124, and 125) who held scientific fragments after the instruction also included evidence of alternative fragments in their responses.

### *Summary of Qualitative Analysis*

1. Preservice teachers' conceptual understandings of tides were categorized as one of five different types. Participants whose conceptual understandings were categorized as scientific demonstrated an understanding of four key ideas to explain the causes of tides. Participants whose understandings were categorized as alternative used different alternative conceptions related to the moon, gravity, the rotation of the Earth, or atmospheric events.
2. Before the instruction, all preservice teachers held alternative or alternative fragments as his/her type of conceptual understanding of tides.
3. Before the instruction, preservice teachers who held alternative conceptions about tides were likely to indicate that there is one tidal bulge on Earth, and they tried to explain this one tidal bulge using various alternative conceptions.
4. After completing an inquiry-based and technology-enhanced instruction about the tides, preservice teachers were more likely to hold a scientific conceptual understanding.
5. After completing an inquiry-based and technology-enhanced instruction which included the study of tides, preservice teachers' types of conceptual understandings of tides was likely to have changed from an alternative to a scientific type of understanding.
6. After completing the inquiry-based and technology-enhanced instruction which included the study of tides, some preservice teachers continued to hold the conception that the moon causes one tidal bulge and that the rotation of the moon

around the Earth during one 24-hour period causes the tides to move with the moon.

### Quantitative Results

This section is organized to present the results of the quantitative analysis of the pre-test and post-test assessment of achievement of tides, and the quantified interview data. Statistical procedures included in the Statistical Program for the Social Sciences (SPSS Version 14.0 for Windows) were used to analyze responses to the pre- and post-instruction achievement tests about tides, and alternative and scientific conceptions. For the data obtained from the pre-test and post-test, the following statistical procedures were applied: a) internal consistency reliability analysis, b) independent sample t-test between instruction group and non-instruction group, c) paired t-test on pre-test and post-test total scores for instruction group, and d) stepwise forward multiple linear regressions with gain as a dependent variable and pre-test items as predictors for the instruction and post-test group. For the quantified data obtained from interviews, the Pearson Product-moment Correlations were computed for the instruction group. The significance level for the analysis was set at .05 for the all statistical inferences. Results from the quantitative data analysis are presented in the following order: Reliability of the Tides Achievement Test, Independent Sample t-test, Paired t-test for Instruction Group, Correlations, Regression Analysis, and Summary of Quantitative Results.

### *Reliability of the Tides Achievement Test*

To assess whether the 19 items that were summed to create the achievement score formed an internally consistent scale, Cronbach's alpha was computed. The alpha for the 19 items before the instruction was .71, and .70 after the instruction which indicates that the items form a scale that has acceptable internal consistency. Seventy-five participants were included in this analysis because some participants did not respond to all questions. The scale mean was 11.03 (SD=2.82) for 75 subjects. Originally twenty-two items were included in the test. The analysis of the pre-test responses resulted in 3 items with negative discrimination coefficients. These three items were omitted from both the pre-test and the post-test in order to increase the overall test reliability. The eliminated questions asked about the definition of gravity in an open response format; the period of semidiurnal tides, and the characteristics of semidiurnal tides. Reliability data is presented in Table 4.7

Variable	No. of Items	N	Alpha
Pre-test Instrument	19	75	.71
Post-test Instrument	19	18	.70

Table 4.7: Cronbach's Alpha internal consistency reliability estimates for pre- and post-test measurement of conceptual understanding of tides

### *Independent Sample t-test*

The independent sample t-test was conducted to compare the participants (n=19) who subsequently participated in the instruction and the participants (n=61) who did not complete the instruction. Results of the independent sample t-test are presented in Table 4.8, and provide a comparison of the instruction and the non-instruction groups on the pre-test scores of achievement about tides and related concepts. The independent sample t-test analysis indicates that there was no significant difference in pre-test total scores for participants who subsequently completed the instruction (M=11.32, SD=2.83) and participants who did not complete the instruction (M=11.48, SD=3.0);  $t_{(78)} = -.21, p = .84$ . These results indicate that the conceptual background of the instruction group (n=19) prior to instruction was similar to the conceptual background of the rest of participants (n=61) based on the 19-item test of achievement on tides and related content, and the interview classification of conceptual understanding. The difference between the proportions of types of conceptual understandings categorized as alternative and alternative fragments between the group of 30 and the sub-group of 19 preservice teachers was assessed with a z-score (Ferguson, 1966). There was no significant difference between the group of 30 and the sub-group of 19 preservice teachers on the proportion of the types of conceptual understandings with regard to their z-score ( $z = .75, p > .05$ ) before the instruction.

These results supported the assumption that the instruction group was a representative sample of the larger population of preservice teachers at the institution where the research was conducted.

Variable	n	M	SD	t	df	p
Pre-test Score						
Instruction group	19	11.32	2.83	-.21	78	.84
Non-instruction group	61	11.48	3.00			

Table 4.8: Comparison of instruction and non-instruction groups on pre-test scores (n=19 instruction group, n=61 non-instruction group)

*Paired t-test for Instruction Group*

A paired-sample t-test was conducted to investigate the relationship of the instructional intervention on the participants' tide achievement test scores. Since 18 participants in the instruction group responded to both the pre- and post-test tides achievement instrument, a paired sample t-test was an appropriate statistical test for that analysis. The results of the paired t-test are presented in Table 4.9, and provide a comparison of the pre-test and post-test measure of achievement on tides and related content. The increase in the test scores from pre-test (n=18, M=11.33, SD=2.91) to post-test (n=18, M=17.55, SD=2.43);  $t_{(17)} = 9.65$ ,  $p < .001$  was statistically significant. This result indicates that the preservice teachers who completed the inquiry-based and technology-enhanced instruction utilizing web-based data archives significantly increased their test scores. Therefore, it appears that the inquiry-based technology-enhanced instruction could have contributed to the promotion of a scientific understanding of tides

within this group of preservice teachers. This inference is also supported by the qualitative findings, which indicated that the preservice teachers were more likely to hold a scientific conceptual understanding of tides after the instruction than prior to instruction.

Variable	M	SD	Mean Difference	t	p
Pre-test	11.33	2.91			
			6.22	9.65	.001
Post-test	17.55	2.43			

n=18, 19 items

Table 4.9: Paired-sample t-test comparison of pre-test and post-test tides achievement scores for the instruction group

### *Correlation*

#### *Correlation Between Alternative Conceptions Before Instruction*

Means and standard deviations for the alternative conceptions about tides held by preservice teachers before the instruction and scientific conceptions about tides held by preservice teachers after the instruction are presented in Table 4.10. Each alternative and scientific conception was graded as 1 for the existence of this conception and 0 for its absence. (Descriptions of abbreviations for Alternative and Scientific conceptions were presented in Table 3.5, Codes and definitions of codes.) From Table 4.10 it can be noted

that the Sci\_GRA (M=.94) and Sci\_TWO (M=1.00) had the highest incidence of occurrence of the scientific conceptions. The highest occurrence of alternative conceptions was Alt\_MOON (M=.82)

Variable		M	SD
Before Instruction	Alt_GRA	.53	.51
	Alt_MOON	.82	.40
	Alt_TIME	.53	.52
	Alt_OTHER	.24	.44
After Instruction	Sci_GRA	.94	.24
	Sci_CENT	.77	.44
	Sci_ROT	.65	.49
	Sci_TWO	1.00	.00

n=18

Table 4.10. Descriptive statistics of alternative conceptions held by preservice teachers before the instruction and scientific conceptions held by preservice teachers after the instruction

The correlations between the occurrence of four alternative conceptions, which emerged from the qualitative findings previously reported in this document, were investigated using the Pearson Product-moment Correlation coefficient and are presented

in Table 4.11. These correlations were computed to determine what relationships existed between the existences of the alternative conceptions which were held by preservice teachers before the instruction.

Variables		Alt_GRA	Alt_MOON	Alt_TIME
Alt_MOON	r	.18		
	p	.485		
Alt_TIME	r	-.41(*)	.18	
	p	.049	.345	
Alt_OTHER	r	-.58(*)	-.11	.25
	p	.013	.683	.343

*Note.* \*  $p < .05$ .  $n=18$

Table 4.11: Correlation and level of significance for relationships between the alternative conceptions related to tides, which were held by preservice teachers before the instruction

There were significant negative correlations between the Alt\_GRA and Alt\_TIME ( $r=-.41$ ,  $n=18$ ,  $p<.05$ ), and between Alt\_GRA and Alt\_OTHER ( $r=-.58$ ,  $n=18$ ,  $p<.05$ ) (See Table 4.11). The first significant negative correlation indicated that when a participant held a gravity-related alternative conception, that is the gravity of the moon causes the water to pile up on one side of the Earth and recede on the other side, they were not likely to hold a time-related alternative conception such as the occurrence of

tides is related to the time of the day or appearance of sun and the moon in the sky. The participants' interview responses indicated that the time of day or appearance of the moon and sun causes the tides, or that the gravity of the moon causes the water to pile up on one side of the Earth.

The second negative significant correlation between Alt\_GRA and Alt\_OTHER indicated that when a participant held a gravity related alternative conception, they were not likely to hold an alternative conception related to weather and Earthquakes.

Preservice teachers either indicated that the gravity of the moon causes the water to pile up on one side of the Earth, or that tides are caused by the weather, Earthquake, or similar forces and they did not mention the Earth, moon, sun, gravity or centrifugal forces. These two significant correlations between Alt\_GRA and Alt\_TIME, and between Alt\_GRA and Alt\_OTHER suggest that the gravity-related alternative conception is a dominant conception among Alt\_GRA, Alt\_TIME, and Alt\_OTHER alternative conceptions. Therefore, gravity-related alternative conceptions tend to appear when the others do not exist and when it is present, the others are perceived to be less probable.

#### *Correlation Between Scientific Conceptions After Instruction*

The correlations between the four scientific conceptions which were held by the preservice teachers after the instruction were investigated using the Pearson Product-moment Correlation coefficient and are presented in Table 4.12. There was a significant positive correlation between the Sci\_CENT conception and Sci\_GRA conception

( $r=.46$ ,  $n=18$ ,  $p<.05$ ). This positive correlation indicated that participants who held a gravity-related scientific conception in which the gravity of the moon and the sun cause tides and at the same time also tended to hold a centrifugal force-related scientific conception in which centrifugal forces due to the Earth's and the moon's rotation around a center of common mass are the main reason for the bulge which is on the side of the Earth farthest away from the Moon. This result was expected for the participants who held the two-tidal bulge model because gravity and centrifugal force concepts represent the two major forces that produce the tides on opposite sides of the Earth.

Variables		Sci_GRA	Sci_CENT	Sci_ROT
Sci_CENT	r	.46(*)		
	p	.043		
Sci_ROT	r	.34	.17	
	p	.184	.512	
Sci_TWO	r	.(a)	.(a)	.(a)
	p	.	.	.

*Note.* \*  $p < .05$ . \*\*  $p < .01$ .

$n=18$

(a) Cannot be computed because Sci\_TWO scores were all the same with zero variance.

Table 4.12: Correlation and level of significance for relationships between the scientific conceptions related to tides, which were held by preservice teachers after the instruction

It is important to note that all participants in the sample held a two-tidal bulge model after the instruction. Thus, there was no variation in the data and no correlation could be produced for the Sci\_TWO conception (i.e., there are two high tides at the same time on opposite sides of the Earth and two low tides also at the same time on the opposite sides of the Earth).

#### *Correlation Between the Alternative and Scientific Conceptions*

The correlation between the scientific conceptions which were held by preservice teachers after the instruction and alternative conceptions which were held by preservice teachers before the instruction were investigated using Pearson Product-moment Correlation coefficient and are presented in the Table 4.13. There were no significant correlations between the scientific and alternative conceptions in this analysis. Lack of a correlation between scientific and alternative conceptions indicated that there was not a pattern of association between scientific and alternative conceptions. This result indicates that the alternative conceptions which participants held before the instruction were independent of the scientific conceptions participants held after the instruction.

Variables		Alt_GRA	Alt_MOON	Alt_TIME	Alt_OTH
Sci_GRA	r	-.24	-.15	-.24	.14
	p	.362	.658	.362	.596
Sci_CENT	r	.03	.11	-.03	-.35
	p	.901	.683	.901	.174
Sci_ROT	r	-.20	-.34	-.20	.12
	p	.434	.179	.434	.648
Sci_TWO	r	.(a)	.(a)	.(a)	.(a)
	p	.	.	.	.

*Note.* \*  $p < .05$ . \*\*  $p < .01$ .

n=18

(a) Cannot be computed because Sci\_TWO scores were all the same with zero variance.

Table 4.13: Correlation and level of significance between the occurrence of scientific conceptions related to tides which were held after the instruction and the occurrence of alternative conceptions related to tides which were held before the instruction

#### *Correlation Between Alternative Conceptions and Tide Achievement Pre-test Items*

The relationship between the type of alternative conceptions held by the preservice teachers before the instruction and the tide achievement pre-test items were investigated using the Pearson Product-moment Correlation coefficient. The significant

correlations are presented in the Table 4.14. (Abbreviations for items prea1, prea2, prea3, and prea4 represent the questions about shape of the Earth, abbreviations for items preb1, preb2... and preb6 represents the questions about role of gravity on tides, and abbreviations for items prec1, prec2... and prec12 represent the questions about the tides.)

There were significant positive correlations between Alt\_GRA and prea1 ( $r=.55$ ,  $n=18$ ,  $p<.05$ ), and between Alt\_GRA and preb6 ( $r=.50$ ,  $n=18$ ,  $p<.05$ ). These significant positive correlations indicated that participants who held the gravity-related alternative conception were likely to draw a sketch illustrating the simplified model of the solar system by showing the sun, Earth, and moon with their orbits. Also, participants who held a gravity-related alternative conception were likely to know that the gravitational attraction of the moon is a greater factor in determining tides than the gravitational attraction of the sun because the Earth is much closer to the moon than to the sun. In summary, the more that participant knew about gravity before the instruction, the more likely they were to hold the alternative conception that the gravity of the moon causes the water to pile up on one side of the Earth and to recede on the other side.

		Alt_GRA	Alt_MOON	Alt_TIME	Alt_OTHER
prea1	r	.55(*)	.32	.00	-.47(*)
	p	.017	.201	1.000	.048
prea2	r	.44	.10	-.12	-.56(*)
	p	.065	.827	.624	.015
preb6	r	.50(*)	.20	-.15	-.48(*)
	p	.035	.426	.555	.045
prec5	r	.45	-.15	-.33	-.54(*)
	p	.063	.555	.176	.022
prec7	r	.08	.00	-.47(*)	-.19
	p	.755	1.000	.048	.453
prec8	r	.35	-.20	-.67(**)	-.21
	p	.154	.426	.002	.405

*Note.* \*  $p < .05$ . \*\*  $p < .01$ .  
n=18

Table 4.14: Correlation and level of significance for relationships between tides achievement pre-test items and alternative conceptions detected before the instruction

There were significant negative correlations between Alt\_TIME and prec7 ( $r=-.47$ ,  $n=18$ ,  $p<.05$ ), and between Alt\_TIME and prec8 ( $r=-.67$ ,  $n=18$ ,  $p<.01$ ). These significant negative correlations indicate that participants who held a time-related alternative conception (i.e., occurrence of tides is related to the time of day or appearance of sun and the moon in the sky) were less likely to know that spring tides occur about twice per month and neap tides occur when the moon is at its first and third quarter. It can be inferred that participants who think that the time of day or appearance of the sun and moon in the sky causes tides were likely to have less knowledge about spring and neap tides. Another inference is that the time-related alternative conception (Alt\_TIME) is indirectly related to the rotation of the Earth. For instance, day and night, sun rise and moon rise, or morning and afternoon are the phenomena which occur as a result of the rotation of the Earth.

There were significant negative correlations between Alt\_OTHER and prea1 ( $r=-.47$ ,  $n=18$ ,  $p<.05$ ), between Alt\_OTHER and prea2 ( $r=-.56$ ,  $n=18$ ,  $p<.05$ ), between Alt\_OTHER and preb6 ( $r=-.48$ ,  $n=18$ ,  $p<.05$ ), and between Alt\_OTHER and prec5 ( $r=-.54$ ,  $n=18$ ,  $p<.05$ ). These significant negative correlations indicate that participants who held alternative conceptions related to tides being caused by rain, wind, Earthquakes, or other movement in the ocean were less likely to draw a sketch illustrating the simplified model of the solar system by showing the sun, Earth, and moon with their orbits; were less likely to know that the moon is closer to the Earth than it is to the sun; were less likely to know that the gravitational attraction of the moon is a greater factor in determining tides than the gravitational attraction of the much larger sun because the

Earth is much closer to the moon than to the sun; and were less likely to know that spring tides are associated with the new moon and full moon phases. These significant negative correlations indicated that participants who indicated that tides are caused by rain, wind, Earthquakes, or other movement in the ocean are less likely to have a good understanding of gravity between the Earth and the moon and they are less likely to have a good understanding of the relationship between the different phases of the moon and the tides. Therefore, before the instruction, these participants tried to explain tides with other events, such as Earthquakes, wind, rain, and movement in the water.

#### *Correlation Between Scientific Conceptions and Tide Achievement Pre-test Items*

Relationships between scientific conceptions which were held by preservice teachers after the instruction and the tide achievement pre-test items were investigated using Pearson Product-moment Correlation coefficient. The correlations and their significance are presented in Table 4.15.

There was a significant positive correlation between the Sci\_GRA and preb3 ( $r=.54$ ,  $n=18$ ,  $p<.05$ ), and a significant negative correlation between the Sci\_GRA and preb5 ( $r=-1.0$ ,  $n=18$ ,  $p<.001$ ). These significant positive correlations indicate that participants who held gravity-related scientific conceptions after the instruction were likely to know that when people walked on the moon they could jump higher than they could back on Earth because the moon exerts less gravitational force than the Earth, and they were less likely to know that the moon exerts a gravitational force on Earth and this gravitational force on Earth is equal to that of Earth on moon. It can be inferred that

participants who held alternative conceptions about gravity before the instruction tended to have a scientific conception of the role of gravity in generating tides after the instruction.

		Sci_GRA	Sci_CENT	Sci_ROT	Sci_TWO
preb3	r	.54(*)	.11	-.02	.(a)
	p	.025	.683	.942	.
preb5	r	-1.00(**)	-.45	-.34	.(a)
	p	.000	.069	.184	.
prec10	r	-.34	-.47(*)	.03	.(a)
	p	.184	.048	.908	.

*Note.* \*  $p < .05$ . \*\*  $p < .01$ .  $n=18$

(a) Cannot be computed because Sci\_TWO scores were all the same.

Table 4.15: Correlation and level of significance for relationships between tide achievement pre-test items and scientific conceptions detected after the instruction

There was a significant negative correlation between Sci\_CENT and prec10 ( $r=-.47$ ,  $n=18$ ,  $p<.05$ ). This significant negative correlation indicates that participants who held the centrifugal force-related scientific conception on the causes of tides after instruction were less likely to know, before the instruction that two tides occur on the

opposite sides of the Earth. In other words, the more participants knew about the role of centrifugal forces in tide generation, the less likely they were to hold the one-tidal bulge model.

### *Regression Analysis*

Stepwise forward multiple regression analysis was conducted to determine the best linear combination of pre-test items for predicting the gain of achievement on tides and tides-related content. Gain scores were obtained by subtracting pre-test item scores from post-test item scores. Three variables, preb3, prec8, and prec10 were identified as significant predictors of gain score. The means, standard deviations, and inter-correlations are summarized in Table 4.16. These three items tested participants' knowledge of the correlation between moon phases and tides, the gravitational pull of the moon, and the presence of two-tidal bulges on opposite sides of the Earth, respectively.

	M	SD	preb3	prec8	prec10
Gain	6.29	2.80	-.52(*)	-.53(*)	-.49(*)
Preb3	.82	.39	-	.07	.02
Prec8	.41	.51		-	.13
Prec10	.35	.49			-

*Note.* \*  $p < .05$ . , n=18

Table 4.16: Means, standard deviations, and inter-correlations for gain score and significant pre-test tide achievement item predictors

The combination of these three variables accounted for 61% of the variance in the gain score which was the dependent variable. All three predictors had negative, significant, standardized regression coefficients, prec8 (beta =  $-.44$ ;  $p < .05$ ), prec3 (beta =  $-.48$ ;  $p < .05$ ), and prec10 (beta =  $-.42$ ;  $p < .05$ ). The standardized beta scores for the three predictors of the gain score were about equal ( $-.44$ ,  $-.48$  and,  $-.42$ ). This indicates that these three predictors equally contributed to explanation of the gain score variance. The regression model was significant ( $F [3, 13] = 9.34$ ;  $p < .05$ ) and yielded an adjusted  $R^2$  of  $.61$ . According to Cohen (1988), this is a large effect. Table 4.17 shows the coefficients and statistical properties for each of the items contributing significantly ( $p < .01$ ) to the prediction of the gain. This indicates that when the participants answered these three items correctly on the pre-test, their gain score was likely to be lower after the instruction. Conversely when the participants answered these three items incorrectly on the pre-test, their gain was likely to be greater. One point that should not be ignored here is that if the participants who answered those three questions on the pre-test correctly do not have as much to learn as those who answered them incorrectly.

Model	Variable	B	Beta	t	p	Partial Correlations
3	(Constant)	10.94		10.14	.00	
	prec8	-2.43	-.44	-2.79	.02	-.61
	preb3	-3.40	-.48	-3.06	.01	-.65
	prec10	-2.39	-.42	-2.68	.02	-.60

Note: Dependent Variable: gain  
Adjusted R<sup>2</sup> =.61  
For model: F (3, 13) = 9.34, \*p<.05  
n=18

Table 4.17: Forward stepwise regression of pre-test tides achievement item scores with the gain score from total pre-test to post-test tides achievement

As further analysis, the correlation between the best predictors, which were preb3, prec8, and prec10, and the other pre-test items were investigated. The only significant correlation was a negative one between the preb3 and preb5 ( $r = -.54$ ,  $n = 18$ ,  $p < .05$ ). Both items measured the same content, which was participants' understanding of the moon's gravity. Table 4.18 presents the number and percentage of right and wrong answers to those three questions. The percentage of correct responses for Preb3 increased from 78 % to 94 % after the instruction, which indicated that participants were aware of the fact that the moon exerts less gravitational force on the people who are walking on the moon than the Earth exerts on people. On the other hand 1 participant (6 %) answered

preb5 correctly before the instruction, which indicated that participants were not aware of the equal gravitational forces between the moon and the Earth on each other. The most popular wrong answer for preb5 was “the moon’s gravitational force on the Earth is less than that of Earth on the moon”. Negative correlation between these two items indicates that participants were likely to indicate that the moon exerts less gravitational force on the people who walk on it, but they were less likely to indicate that gravitational forces between two objects are equal to each other.

Items	Pre-test	Post-test
b3		
Right	14 (78 %)	17 (94 %)
Wrong	4 (22 %)	1 (6 %)
c8		
Right	7 (39 %)	16 (89 %)
Wrong	11 (61 %)	2 (11 %)
c10		
Right	7 (39 %)	16 (89 %)
Wrong	11 (11 %)	2 (11 %)
n=18		

Table 4.18: Number and percentage of right and wrong answers for items preb3, prec8, and prec10

The only significant correlation with prec8 was with prec7 ( $r=.63$ ,  $n=18$ ,  $p<.01$ ). Both items measured the same construct which is the relationship between phases of the moon and tides. The percentage of right answers for prec8 increased from 39% to 89% after the instruction. The positive correlation between these two items indicated that participants were not aware of the correlation between the moon phases and the spring and neap tides before the instruction.

The only significant correlation with prec10 was a positive one with prec3 ( $r=.47$ ,  $n=18$ ,  $p<.05$ ). The positive correlation between these two items indicated that participants were less likely to be aware of the two-tidal bulge model before the instruction. The percentage of right answers for prec10 increased from 36 % to 89 % after the instruction on the item prec10.

A graphical model which represents the results from the multiple regression model with gain score as the dependent variable, and items preb3, prec8, and prec10 as the independent variable predictors are presented along with the significantly correlated items with these predictors in Figure 4.4. According to the regression model, knowledge of two-tidal bulges, correlation between the phases of the moon and tides, and moon's gravity uniquely contributed to gain score. These Results indicated that more detailed instruction on these three concepts should contribute to increased student understanding of tides.

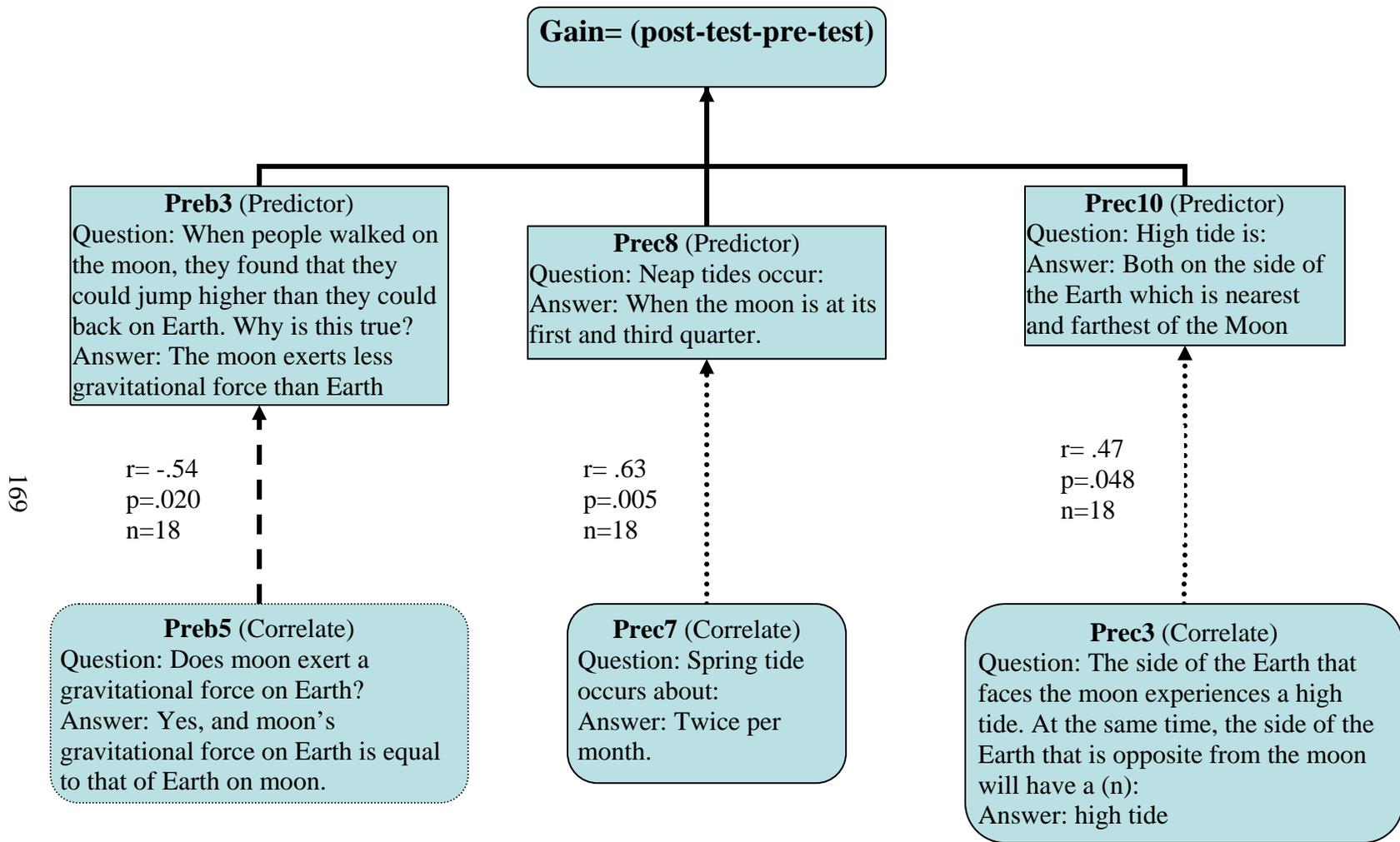


Figure 4.4: Relationships between the gain score, the pre-test tides achievement item predictors, and other correlates.

### *Summary of Quantitative Results*

1. The test used to measure tides achievement before and after the instructional intervention was a reliable 19-item instrument with a Cronbach's Alpha of .71 for the pre-test and .70 for the post-test.
2. The preservice teachers, who completed the instructional intervention, and participated in both pre- and post-interview, and completed both the pre- and post-test achievement measures were not significantly different than the other preservice teachers in the institute where the research was conducted. Therefore, it can be inferred that the instruction group was a representative sample of the larger population of preservice teachers.
3. There was a statistically significant increase in participants' test scores after completing the inquiry-based and technology-enhanced instruction which utilized Web-based archived data. It appears that, based on the significant increase in participants' test scores, this type of instructional intervention may have been an effective teaching methodology for promoting scientific understanding of tides within this group of students.
4. A significant negative Pearson Product-moment Correlation between the Alt\_GRA and Alt\_TIME, between Alt\_GRA and Alt\_OTH before instruction indicated that when Alt\_GRA exists the other alternative conceptions were less likely to exist. It can be inferred that Alt\_GRA is a dominant alternative conceptions among the Alt\_GRA, Alt\_TIME, and Alt\_OTHER conceptions before the instruction.

5. A significant positive Pearson Product-moment Correlation between the occurrence of Sci\_CENT and Sci\_GRA after instruction indicated that in the case of existence of one of these conceptions the other conception also is likely to exist. This outcome would be expected because these two scientific conceptions are the two major conceptions in the cause of tides.
6. No significant correlation was observed between the before instruction alternative conceptions and after instruction scientific conceptions, which indicate that alternative conceptions were independent of the scientific conceptions.
7. A significant positive Pearson Product-moment Correlation between Alt\_GRA conception and individual pre-test items indicated that participants who were likely to have a scientific understanding of gravity before instruction were likely to hold Alt\_GRA conception before the instruction.
8. A significant negative Pearson Product-moment Correlation between Alt\_TIME conception before instruction and individual pre-test items indicated that participants, who held the Alt\_TIME conception, were less likely to know about the spring and neap tides.
9. A significant negative Pearson Product-moment Correlation between Alt\_OTHER conception before instruction and individual pre-test items indicated that participants, who held the Alt\_OTHER conception, were less likely to have a good understanding of gravity between the Earth and the moon, and they were less likely to have a good understanding of the relation between the different locations of the moon in the sky and the tides.

10. A significant positive Pearson Product-moment Correlation between Sci\_GRA conception after instruction and individual pre-test items indicated that participants, who held Sci\_GRA conception after instruction, were more likely to know about the effects of gravity on tides before the instruction.
11. A significant negative Pearson Product-moment Correlation between the Sci\_CENT conception before instruction and individual pre-test items indicated that the more participants knew about the role of centrifugal forces in tide generation, the less likely they were to hold the one-tidal bulge model.
12. Three predictors, which were items on the pre-test for tide achievement (preb3, prec8, and prec10), were identified as significant predictors of gain score for tide achievement. These three predictors were about gravity, phases of the moon, and two-tidal bulge model.

## CHAPTER 5

### DISCUSSION AND CONCLUSION

#### Introduction

The purpose of this mixed methods study was to describe and understand preservice teachers' conceptions of tides and to explore an instructional strategy designed to promote the learning of scientific concepts. The participants were preservice teachers in three initial licensure programs at a major Midwestern research university. A total of 80 graduate students, 18 males and 62 females, enrolled in secondary, middle, and early childhood teacher licensure programs completed a multiple-choice assessment of their knowledge of tides-related concepts. Thirty of the 80 participants were interviewed before the instruction. Nineteen of the 30 students who were interviewed also participated in the instruction and were interviewed after the instruction. In addition to completing both interviews, these 19 students also completed the pre-test and 18 of them completed the post-test.

Participants in the current study were taught using an inquiry-based technology-enhanced instruction, which followed a textbook chapter titled *Discovering*

*Tidal Patterns* (Trundle & Krissek, 2005). During the tides instruction, participants conducted investigations by accessing on-line data and importing the data into spreadsheets for data analysis. Participants created and interpreted line graphs of tides and tidal ranges by using actual on-line tidal data. Additionally, participants correlated moon phase data with tidal range graphs and tried to describe the relationships between tides and moon phases. By integrating these two phenomena, participants modeled and explained the causes of tides. Also, participants analyzed tidal patterns for different geographic locations in order to see variations in tidal data, they used an on-line simulation of tides, and they participated in a psychomotor model of the causes of tides.

Data regarding the participants' conceptual understandings were collected before and after the instruction using both qualitative and quantitative data collection methods (Gay, 1996). A multiple-choice pre-test for tides achievement was developed by the researchers. The same test was used before and after the instructional intervention. The independent t-test, paired t-test, Pearson correlation, and a stepwise regression were used for quantitative analysis. In addition to the multiple-choice test, structured interviews (Glesne, 1999) were conducted with a subset of participants before and after the instruction. The structure of the interview protocol for the participants was modeled after the interview protocol developed by Trundle et al. (2002). The content validity of the interview questions was judged by two experts, one a science educator and the other an oceanographer. In addition to interviews, participants were asked to write a short journal after instruction to provide insight into their perceptions of the instruction. The constant comparative method was used to analyze the qualitative data (Glaser & Strauss, 1967).

This chapter is organized around conclusions generated from the quantitative results of the pre-test and post-test responses, the quantified interview data, and from the qualitative findings from the pre- and post-instruction interview responses, including the use of models and drawings. This chapter contains the following major sections: 1) Assertions and Discussions, 2) Discussion of Using Web-based Archived Data, 3) Discussion of Conceptual Change, 4) Implications for Teacher Education, 5) Implications for Classroom Practice, 6) Recommendations for Future Research, and 7) Conclusions.

### Assertions and Discussions

**Before the instruction, preservice teachers were very likely to hold alternative conceptions about the tides and causes of tides.** Before the instruction, all of the participants who were interviewed held alternative or alternative fragments as their conceptual understandings. Some of the findings of previous studies were consistent with the findings of the current study. A summary table of previous studies which investigated the understanding of tides is provided in Table 5.1.

From the findings of the current study with 80 preservice teachers combined with the results of previous studies with a combined total of 263 preservice teachers (Skam, 1994; Viiri, 2000a), it can be inferred that preservice teachers, despite any previous instruction they may have had on tides before entering their methods courses, were likely to hold alternative conceptual understandings of tides.

<b>Author &amp; year</b>	<b>N</b>	<b>Participants</b>	<b>Data collection</b>	<b>Scientific conception before the instruction</b>
Viiri (2004)	31	Eighth grade students	-Open response -Multiple-choice	9.8 %
Viiri (2000a)	130	-Secondary school pupils (n=28) -First year primary school teacher trainees (n=61) -Subject teacher trainees (n=41)	-Open response -Multiple-choice	2.3 %
Galili& Lehavi (2003)	103	High school physics teachers (n=75)  University physics major students (n=28)	-Open response -Figure interpretation	0 %
Skamp (1994)	81	Preservice primary teachers	-Open response	22 %
Current study (2006): Instruction group	19	Preservice teachers	Structured interview -Model use -Drawing -Verbal response  Achievement test -Multiple-choice -Drawing questions	0 %
Current study (2006) Non-Instruction group	61	Preservice teachers	Achievement test -Multiple-choice -Drawing questions	0%

Table 5.1: Summary of previous reports of participants' understandings of tides before the instruction

The finding, that none of the participants had a scientific conception of tides before the instruction, was consistent with the findings of Viiri (2000a). Viiri found that only 2.3 % of the whole sample including secondary school students, subject teacher trainees, and primary school teacher trainees (preservice teachers) provided the correct explanation of the tides. Viiri's sample included subject teacher trainees who were in their 3<sup>rd</sup> or 4<sup>th</sup> year at the university and studying their main subject. Participants who held a scientific understanding of tides (2.3 %) were among the subject teacher trainees. None of the primary school teacher trainees in Viiri's study had a scientific understanding before the instruction. Since the participants of the current study were preservice teachers, the findings of the current study are consistent with the findings of Viiri's study which included a similar sample. The findings of the current study, specifically that none of the participants had a scientific conception of tides before the instruction, were also consistent with Galili and Lehavi's (2003) study, which included groups of participants who were high school physics teachers. Galili and Lehavi reported that none of the high school physics teachers and university physics majors had a scientific understanding of tides before the instruction. In summary, the preservice teachers in the current study held alternative conceptions of tides before the instruction, and this finding is consistent with other studies conducted with teachers.

Although the findings of the current study were consistent with some previous studies, the results reported here were inconsistent with Skamp's (1994) study, which included preservice teachers as participants. Skamp found that 22.2 % of the entire sample agreed with an acceptable scientific reason which read "There are two high tides and two low tides each day". The large difference between Skamp's study and the current

study may be due to the data collection methods. Skamp did not conduct in-depth interviews like the ones used in this study. Skamp's questions were factual questions and correct responses to these questions may not have meant that students understood the concept because students sometimes can recall and repeat what they have heard from their instruction without a thorough understanding of the concept (Vosniadou, 1994). In conclusion, the difference between the current study and Skamp's study was most likely due to the research designs. However, despite this difference in findings, neither group had a majority of participants who understood tides without instruction.

**Preservice teachers who held alternative conceptions about tides before instruction were likely to express the view that there is one tidal bulge on the Earth, and they tried to explain this one tidal bulge through the application of various alternative conceptions.** These alternative conceptions were related to the moon, gravity, time of day, and atmospheric and environmental events. Some participants expressed the view that gravitational pull of the moon causes the water to pile up on one side of the Earth which is closest to the moon and causes the low tides on the side of the Earth farthest away from the moon. This particular alternative conception previously was reported by Galili and Lehavi (2003), and Viiri (2000a).

The qualitative and quantitative analyses for the current study indicated that participants seemed to relate tides directly to the moon's gravitational pull in general. Other tides generating forces were usually ignored. Anchoring to the conception that the gravitational attraction of the moon generates, the one-tidal bulge model of tides appeared to be the basis for development of this alternative conception. Gravitational forces are the forces which have a pulling effect on another body in space. The

participants seemed to know some information about gravitational forces from their daily experiences and from their previous science classes. They tended to think that gravitational forces of the Earth on the moon worked only in one direction to pull objects toward the Earth. Therefore, they indicated that the water on the Earth was pulled only in one direction toward the moon on the side of the Earth which was facing the moon. They expressed the view that the water on the other side of the Earth which was farthest away from the moon was also pulled toward the moon, causing one high tide on the side of the Earth facing the moon and one low tide on the side farthest away from the moon. Some participants even reported having some formal instruction on tides yet they seemed to hold very coherent alternative models to explain a one-tidal bulge model including gravitational forces.

The participants seemed to express the view that since the tide-generating forces are caused only by the moon, and we should have tides when we see the moon in the sky. Based on these assumptions, if the moon's gravity is the only tide-generating force, there should be only one tidal bulge during the day. Participants indicated that the gravity of the moon is weakest on the opposite side of the Earth, which means participants seemed to be aware of the inverse relationship between gravity and distance (i.e., the closer the moon is to the Earth, the stronger the gravitational pull). However, this scientific view may have generated an alternative conception, the one-tidal bulge, because the participants seemed to ignore other tide-generating forces.

Another alternative conception was related to the time of day and appearance of the moon and the sun in the sky. Skamp (1994, p.65) reported this alternative conception as "high tides occur when the moon is visible (maybe at night)". Participants might have

tried to make connections between the tides and other daily events such as the rise and set of the sun. It seems that participants tried to make a connection between the rotation of the Earth and tides by connecting the tides to the different times of the day. These participants expressed the view that the rotation of the Earth on its axis causes day and night and as a result the sun appears in the sky during the day and the moon appears in the sky during the night. Of course this viewpoint includes a misconception about when the moon actually can be observed. In reality, the sun can only be observed during the day. However, the moon can sometimes be observed at night and at other times during the day depending on the moon phase. The rotation of the Earth does play a role in the occurrence of two high tides and two low tides in each day, but it does not have any role in the actual causes of the tides and tidal bulges.

A different alternative conception was related to the moon by some preservice teachers. The participants' interview responses and their use of the models indicated that some preservice teachers seemed to think that the moon orbits the Earth every 24 hours and tides move with the moon's revolution around the Earth within a single day. This alternative conception was also reported by Skamp (1994, p.65) who reported it as "Tides are caused by the moon orbiting the Earth every 24 hours". In reality, the moon completes its orbit around the Earth in almost 30 days. However, some participants indicated that the moon's orbit of the Earth takes only 24 hours. Based on this view, it can be inferred that some preservice teachers held a view that was similar to a geocentric model of the solar system. A geocentric model is presented by Vosniadou (1994) as a model where "the sun and moon revolve around the Earth once every day" (p.57). The participants' model was not exactly the same as Vosniadou's geocentric model. The only

similarity between Vosniadou's geocentric model and participants' responses was the period of the moon cycle around the Earth. There was no data about the participants' ideas of the sun's revolution time around the Earth. No investigations were conducted in the current study to further explore the geocentric model of the solar system. Participants might have had a model which was heliocentric, and they might not know that the revolution of the moon around the Earth takes more than 24 hours.

Another alternative conception participants held was related to Earthquakes, wind, rain, and movement in the ocean. That alternative conception also was reported by Viiri (2000a). One possible explanation for the idea that tides are caused by winds or Earthquakes could be that the tides might be confused with the ocean waves because waves are clearly observable movements in the ocean and caused by the factors listed above. In this case, the participants explained tides with the events which cause waves. Earthquakes also were presented as one of the causes of tides. However, Earthquakes in the ocean create large tsunami waves not daily tides. In addition, participants confused the tides with other atmospheric events such as cyclones and anticyclones. One possible explanation of this could be that hurricanes and tsunami disasters had occurred recently in different parts of the world, and these disasters were covered broadly on the news. Hurricanes and tsunami are usually reported along with satellite images of the upper atmosphere on the background. Since the participant expressed the view that tides were the ocean waves, it seems reasonable that they might indicate that these large scale atmospheric events cause tides. In summary, participants had a one-tidal bulge model before the instruction, and they seemed to try to explain their models with alternative conceptions, which were based on their existing knowledge.

**Preservice teachers who had instruction were very likely to hold a scientific conceptual understanding of the tides after the instruction.** The majority of the participants (52 %) in this study held a scientific conceptual understanding of tides, a small group (16%) held scientific fragments as their conceptual understandings, and the rest of the participants (32 %) held scientific fragments with alternative fragment as their conceptual understandings after the instruction. None of the participants held a one-tidal bulge model after instruction. Only Viiri (2004) looked at the conceptual understandings in middle school students after instruction and his findings were consistent with this study. Viiri found that all of the students in the first-year group had a two-tidal bulge model which was mostly scientific, and in the second-year group 16 out of 17 students had a two-tidal bulge model with a scientific explanation of the cause of tides. This consistency with Viiri's study indicated that with the proper instruction, a scientific understanding of tides can be promoted with middle school students (Viiri) and with the preservice teachers in the current study.

Even though the current study and Viiri's (2004) study found similar results with different age groups, the two studies followed different instructional interventions. Viiri used a research-based instruction which included the teacher's presentation and limited discussions between the teachers and students and between the students and students. The instruction in the current study was an inquiry-based and technology-enhanced instruction which utilized Web-based data archives for tides instruction. Viiri's instruction required approximately 50 minutes. Whereas the current study's instruction required approximately 180 minutes. The instructional differences between Viiri and this study are presented in Table 2.6 in Chapter 2.

The difference in the instruction time between Viiri (2004) and the current study could be of concern for practice. Viiri's study involved much less instructional time. Other researchers and science educators might ask why another type of instruction which requires 180 minutes is needed if there is a shorter instructional time strategy that can reach the same goal. The current study does not claim that the instruction used here is better than Viiri's instruction because both studies applied different approaches to tides instruction. Viiri implemented the astronomy approach to tides instruction while the current study implemented the oceanography approach. As presented in Chapter 2, the astronomy approach uses the hypothetical equilibrium model which indicates that the Earth is uniformly covered with the same depth of ocean and environmental factors are ignored in the model. That model is based on a theoretical explanation instead of a real-world model. The current study applied the oceanography approach which applies a dynamic model that considers the existence of continents and different ocean-depths, and most importantly, it used real data to explain tides. In addition to developing a conceptual understanding, the use of real data in the current study also allowed for the application and development of inquiry skills such as organizing data (e.g. tables and spreadsheets), representing data (e.g. graphs), identifying patterns, and analyzing data. In the oceanography approach, participants needed more time to process the data while in the astronomy approach there was no inclusion of inquiry or inquiry skills. Also, the instruction applied in the current study enabled students to practice scientific inquiry within real-life situations, which is recommended by the National Research Council (NRC, 2000). Another advantage of the instruction used in the current study is that participants had the opportunity to develop content knowledge as well as inquiry skills.

The development and application of inquiry skills is a major difference when compared to Viiri's instruction, which focused on development of content knowledge and did not pay attention to developing inquiry skills.

**Preservice teachers who did not have a good understanding of gravitational forces, phases of the moon, and centrifugal forces were likely to have an alternative conception of the causes of tides.** Based on the statistical analysis, it can be inferred that participants who held a good understanding of gravity, moon phases, and centrifugal forces were more likely to increase their scientific understanding of tides after the instruction. Therefore, future instructional interventions perhaps should pay more attention to teaching those concepts before teaching the tides. Previous studies did not report any findings related to this assertion.

**Even after the instruction in this study, many of the participants developed a scientific understanding of tides, some preservice teachers tended to maintain their alternative conceptions along with the development of some attributes of a scientific understanding after the instruction.** After the instruction, all 19 preservice teachers held a two-tidal bulge model with a complete scientific, scientific fragments, or scientific fragments with alternative conceptions as his/her type of conceptual understanding. The six participants, who held the alternative conception that the rotation of the moon around the Earth during one 24-hour period causes the tides to move with moon, continued to hold this alternative conception after the instruction. Viiri (2004) did not mention this alternative conception in his study. The most plausible explanation as to why some preservice teachers continued to hold this alternative conception might come from their intuitive believe that the moon revolves around the Earth once in each day. That

conception might be categorized under the framework theory (Vosniadou, 1992) because it is a conception which may constrain a scientific understanding of tides after instruction. Since this conception persisted after instruction, this alternative conception appeared to be very resistant to change.

#### Discussion Related to Using Web-based Archived Data

**Utilizing Web-based archived data sources appears to be correlated with conceptual change among preservice teachers.** Positive effects of using technology-supported instruction in science classes have previously been reported in a meta-analysis (Bayraktar, 2002), and positive effects of using on-line data have been reported in other studies (Edelson, 2001; Etkina et al., 2003; Lin et al., 2002; Songer, 1996; Wallace et al., 2000). Previous research indicated that using real-time data in instruction increased the participants understanding of the content (Lee & Songer, 2003; Post-Zwicker et al., 1999; Songer, 1996). In addition, previous research reported that Web-based activities can be motivating because students have control over the learning process (Ng & Gunstone, 2002; Songer, 1998).

Even though little research exists on using on-line data and its potential effectiveness for instruction, some science educators have suggested several advantages of using Web-based archived data in science instruction (Trundle, in press; Windschitl, 1998). Easily accessible, up-to-date, or archived data provide large quantities of data and students have an opportunity to access the data at any time and from any location. They also are able to obtain data safely without going to the field (e.g., going to ocean for tide data or going out at night for moon data).

The participants' test scores in the current study increased significantly after the instruction with Web-based data in an inquiry-based lesson and most of the participants' conceptual understandings of tides changed to scientific after the instruction. Since participants did not participate in any other astronomy related activities during the time period they were involved in the current study, the instructional intervention may be a major reason for the positive gain. One possible explanation could be the positive effects of using archived Web-based data in tides instruction. As a result of doing inquiry with Web-based, archived data, participants' understandings of the content changed. A discussion of possible advantages of using on-line data in the current study follows.

Using Web-based, archived data increased the quantity of data that participants could access and analyze in a short amount of time. Participants could access tidal data for several months and from various geographic locations during class time. Also, they could use data from a broader range of time intervals to make more accurate analyses. In the current study, participants accessed, organized, and used tidal data for a two month period. Physically, it was not realistic to expect students to make actual observations in nature for two months and collect data in real-time for that extended time period.

Accessing archived data is especially important for the students who do not live close to the ocean and do not have an opportunity to conduct their own observations. For instance, the current study was conducted in a Midwestern town which is located far from the ocean. Even when participants might live close to the ocean, it might not be possible to make their own observations because of safety or accessibility issues.

Logistically, using Web-based, archived data was an effective way of doing inquiry in the current study. In order to get meaningful results for tides analysis,

participants needed to use at least two months of data in order to see reoccurring patterns. Actually collecting data and entering it into spreadsheets is very time consuming, and can be difficult for students. Archived, Web-based sources provide data that are already entered and stored in a format which students can easily access. Also, participants can access the data from different geographic locations including other countries or other continents to develop and/or extend their model of tides. Students can access the data sources any time and at various locations as long as they have an Internet connection. They could possibly conduct their investigation at school, at home, or at the library. Also, numerous groups or individuals could use the same sets of data and have the opportunity to compare their findings.

By using on-line data, these preservice teachers not only conducted scientific inquiry with actual tidal data, but also they were involved in an inquiry-based teaching activity, which provided them a model of how to integrate inquiry into their lesson for their future classes. Thus, the instruction used in this study helped develop the teachers' understandings of tides, and it modeled inquiry-based pedagogy as recommended in the National Science Education Standards (NRC, 1996).

Besides the advantage of using archived data, the instruction used in this study avoided the problems reported in previous studies (Hoffman et al., 2003) which used Web-based instruction. Other researchers reported problems including difficulty finding appropriate URLs and time issues. In the current study students were provided web addresses where they were able to access, import, and organize the data for their analysis. Also they were provided the web addresses for a tides animation. These supports seemed

to help participants to access the information more quickly and it allowed for more efficient inquiry.

In summary, this oceanography approach to tides instruction applied a realistic model for instruction, which utilized the real-time data and considered environmental factors to explain tides in a specific location. Using on-line data in this type of inquiry-based instruction appeared to be effective and it provided an appropriate model for inquiry instruction. The findings of the current study provide evidence that archived, on-line data used with inquiry instruction has the potential to teach the concepts of tides and the potential to promote conceptual change.

#### Discussion of Conceptual Change

Vosniadou (1994) indicated that students may have a consistent model to explain observed phenomena. Some participants in this study seemed to hold a consistent model of the tides before the instruction. The consistent model included a one-tidal bulge model caused by the gravitational attraction of the moon. Participants also expressed the view that tides were related to the time of day or other natural events such as earthquakes, wind, rain, and waves. The explanations of the causes of tides were not the same for each person before instruction. The different participants applied various explanations to explain the tides. However, a one-tidal bulge model of tides was a common element for all the participants. A one-tidal bulge model was consistently included within participants' responses to interview questions, their drawings, and use of models. All of the pre-instruction explanations for tides appeared to be consistent across participants.

According to Vosniadou (1994), conceptual change occurs through the modification of mental models as a result of enrichment or revision. Enrichment, which is similar to assimilation in Posner et al.'s conceptual change model, is the addition of the new information into the existing model and the new information is usually added through instruction (Vosniadou). Centrifugal forces were not used by the participants to explain tides before the instruction in the current study. Preservice teachers did not talk about the centrifugal forces and they gave no evidence in their responses that indicated that they knew about this concept. Specific interview questions were targeted at determining participants' conceptions of centrifugal forces and how they related to tide-generating forces. Before instruction, none of participants expressed an understanding of a two-tidal bulge model which only could be explained with both gravitational and centrifugal forces. The instructional intervention focused on the introduction of centrifugal forces along with gravitational forces to explain tides. As a result of the instruction, the preservice teachers in this study appeared to incorporate centrifugal forces into their pre-instruction understandings, and they applied the concept to explain the two-tidal bulge model involved in causing tides. Since centrifugal forces did not conflict with the participants existing understandings, it seemed easier for participants to integrate this concept into their model of tides. One possible explanation of this smooth enrichment process could be that the participants did not have any previous knowledge about the relationship between centrifugal forces and tides. Preexisting knowledge sometimes prevents the promotion of scientific concepts. Their existing explanation did not provide the solution to explain a two-tidal bulge model. Therefore, the participants may have been dissatisfied with their explanations of tides and they may have assimilated

centrifugal forces, which was more plausible and fruitful (Posner et al., 1982) for them, into their explanation of tides.

A second kind of conceptual change, which was explained by Vosniadou, is “revision” (Vosniadou, 1994, p. 46). Revision has been described as more difficult to accomplish during instruction because revision involves changes in individual conceptions, presuppositions, or relational structures. Initially, all the preservice teachers held a one-tidal bulge model in the study. Their one-tidal bulge model appeared to be a coherent model which was based on different explanations. After the instruction, none of the participants held a one-tidal bulge model. Almost half of the preservice teachers (52 %) revised their one-tidal bulge model into a scientific model which included a two-tidal bulge models. The remainder of the participants either held scientific fragments (16 %) or scientific fragments with alternative fragment (32 %) as their conceptual understandings after the instruction while holding a two-tidal bulge model. One possible explanation for the modification of the alternative one-tidal bulge model to a scientific two-tidal bulge model would be enrichment through instruction. Enrichment of the current conceptual framework may have played a major role in revision of the one-tidal bulge model. Some participants who held scientific fragments with alternative fragment as their conceptual understandings after the instruction could not make the revision of their framework theory which included the entrenched belief that the moon rotates around the Earth every 24 hours. That conception appeared to be hard to change for some participants. Thus, this idea was carried from before instruction and it persisted after instruction. It might be possible to revise the framework theory and promote a scientific understanding of tides with additional proper instruction on moon phases and the moon’s orbit of Earth.

## Implications for Teacher Education

Several implications for preservice and inservice teacher education can be drawn from the findings of this study.

It is important that teachers should have a good understanding of the content they are expected to teach and their understandings should extend beyond common knowledge of the content. If teachers hold alternative conceptions, they may have difficulties identifying their students' alternative conceptions and successfully addressing them (Calik & Ayas, 2005). The current study showed that all of the preservice teachers who participated in the pre-instruction interviews held alternative conceptions or alternative fragments as their conceptual understandings. Without instruction these preservice teachers would most likely have taken their alternative conceptions about tides into their future classrooms and they may have taught their alternative ideas about tides to their students. Therefore, the results of this study suggest that more content knowledge of fundamental astronomy concepts should be introduced to preservice teachers and inservice teachers during their preservice training or during professional development. A lack of content knowledge or the holding of misconceptions about key standards-based concepts may be transferred to students. Also, teachers who lack an understanding of key content may misinterpret or misunderstand the national or state standards they are expected to implement (Ucar, Trundle, & Krissek, 2006).

Science and science education professors who are teaching science content in preservice teacher-training programs should be aware of preservice teachers' alternative conceptions and modify the content and instructional practices of the courses to address

the alternative conceptions. These courses also should try to promote a scientific understanding of the content. An understanding of tides requires a good understanding of other content such as the moon's cycle, gravity, and centrifugal forces. Before teaching tides, these prerequisite concepts need to be addressed.

### Implications for Classroom Instruction

Previous studies (Galili & Lehavi, 2003; Skam, 1994; Viiri, 2000a; 2004) combined with the result of the current study indicate that students across grade levels are likely to hold alternative conceptions about tides and the cause of tides. With an effective instructional strategy, a scientific understanding of tides can be promoted. The inquiry-based instruction used in this study appeared to offer a promising practice for promoting a scientific understanding of tides. Students should be encouraged to build their own knowledge within a constructivist learning environment where they can actively take part in their learning process, including the design of experiments and the collection, analysis, and interpretation of data to implement the findings (Vosniadou, 2001a). With the integration of technology into the science classroom used in this study, the students had the opportunity to actively participate in their learning. The inquiry-based and technology-enhanced instruction, which utilized Web-based data sources, seemed to be an effective instructional strategy to teach tides for the preservice teachers in the current study. The instructional intervention used in this study was designed for use in middle school and high school classrooms and it can be modified for different grade levels. The Web-based data used to teach tides in this study not only are applicable to teaching the content related to tides, but it may be an effective instructional strategy for other content

where teachers want to make connections between real-life examples and science instruction. In addition, the technology-enhanced instruction could be helpful for teaching content which includes movement and perceptions in three-dimensional space. Some content might be hard to teach within traditional textbook-based classrooms because of the limitation to two-dimensional media. Therefore, the instruction applied in the current study could be a fruitful and promising instructional strategy for teaching astronomy in different grade levels, and it has the potential to be modified for different content.

### Recommendations for Future Research

This study was conducted with a small group of preservice teachers who were enrolled at a large research university. Future research should focus on increasing the sample size of the study in order to increase the generalizeability of the findings. Since this study focused on describing the conceptual understanding of tides without any intent to generalize the findings to an entire population, additional studies are needed to accomplish this mission.

The sample for this study included students who were enrolled in a Master's level class in a preservice licensure program. Tides are included as recommended content in the state standards for the middle school students, especially for 8<sup>th</sup> graders. Thus, middle school typically is the place where students are introduced to the content of tides (NRC, 1996). Therefore, future studies should focus on middle school students' conceptions of tides in order to develop a better understanding of what their intuitive knowledge is before they receive formal instruction. Since the current interview protocol covers all the

appropriate aspects of tide concepts, the current interview protocol offers a possible mechanism to gather data from middle school students.

The participants' understandings of gravitational forces between the moon and the Earth was problematic for participants in this study. They explained Earth's tides using the gravitational attraction of the moon, but they could not explain hypothetical moon tides with the reciprocal gravitational forces of the Earth on the moon. This finding indicates that the participants did not have an accurate perception of the gravitational forces between the moon and the Earth in their explanation of causes of tides. Thus, the perception of the preservice teachers was that from the Earth perspective, the moon affects the Earth's tides, but from the moon perspective the Earth does not affect the moon. This finding presents another potential research area. In addition to tides on the Moon, tides on the Earth's crust should be investigated because tides do not occur only in the ocean.

The current study utilized an interview protocol developed specifically for investigating preservice teachers' conceptual understandings of tides and the cause of tides. The interview protocol focused specifically on preservice teachers' conceptions of tides. Future research might modify the interview protocol to link other Earth and space related concepts (e.g., moon phases, shape of the earth).

Future research might repeat the current study with an experimental design (control group) with participants who are preservice teachers or middle school students. An experimental design would allow for a direct comparison between the control and experimental groups and indicate tentative effectiveness of the inquiry-based and technology-enhanced instructional intervention. Within an experimental design the

findings of the study could be generalized to a larger population and have potential for more impact on the teaching and learning of tides at different grade levels. In addition, a longitudinal follow up study is recommended in order to see how participants' understandings of tides evolve over time. The durability of learning presents a major problem for science education (Georghiades, 2000). Therefore, conceptual change should be monitored to identify and describe conceptual pathways and any decay of the learned concepts.

The last recommendation is that future studies investigate the development of inquiry skills after the instruction. Participants conducted scientific inquiry in the current study and undoubtedly developed some inquiry skills. These skills were not measured in this study. Therefore, future studies should focus on measuring the level and types of inquiry skills acquired after completing inquiry-based and technology enhanced instruction.

### Conclusions

Tides are specifically recommended by the National Science Education Standards (NRC, 1996) for inclusion in science teaching in the United States. The concept of tides incorporates several other concepts, such as gravity, centrifugal forces, phases of the moon, shape of the Earth, and rotation of the Earth on its axis. Describing students' understandings of tides before instruction and investigating potentially effective methods to teach tides is an important task for researchers. Both teachers and students should be introduced to alternative instructional methods to understand this complex phenomenon. The current study focused exclusively on tides concepts with a mixed method analysis.

Both qualitative and quantitative data indicated that preservice teachers held alternative conceptions about tides before the instruction. After completing an inquiry-based and technology-enhanced instruction, participants' conceptual understandings of tides changed. The instructional intervention applied in the current study appears to be a promising teaching strategy for tides-related concepts and it offers potential for other content similar to tides. Using archived, on-line data seemed to be effective in promoting conceptual change within preservice teachers. Teachers should try to make use of archived on-line data, which is easily and publicly available in most cases. In conclusion, this study demonstrated that with a well-designed inquiry-based and technology-enhanced instruction, a scientific understanding of tides can be promoted. Web-based, archived data offers a promising instructional method to integrate inquiry into science classes and it seems to facilitate conceptual change.

## REFERENCES

- Atwood, R. K., & Atwood, V. A. (1996). Preservice elementary teachers' conceptions of the causes of seasons. *Journal of Research in Science Teaching*, 33(5), 553-563.
- Atwood, V. A., & Atwood, R. K. (1995). Preservice elementary teachers' conceptions of what causes night and day. *School Science and Mathematics*, 95, 290-294.
- Baxter, J. (1989). Children's understanding of familiar astronomical events. *International Journal of Science Education*, 11, 502.
- Bayraktar, S. (2002). A meta-analysis of the effectiveness of computer-assisted instruction in science education. *Journal of Research on Technology in Education* 34, 173-188.
- Beaujardiere, J.-F. d. L., Cavallo, J., Hasler, A. F., Mitchell, H., O'Handley, C., & Shiri, R., White, R. (1997). The GLOBE visualization project: Using www in the classroom. *Journal of Science Education and Technology*, 6(1), 15-22.
- Beeth, M. E. (1998a). Teaching for conceptual change: Using status as a metacognitive tool. *Science Education*, 82(3), 343-356.
- Beeth, M. E. (1998b). Teaching science in fifth grade: Instructional goals that support conceptual change. *Journal of Research in Science Teaching*, 35(10), 1091-1101.
- Bell, P., & Linn, M. C. (2000). Scientific arguments as learning artifacts: Designing for learning from the web with KIE. *International Journal of Science Education*, 22(8), 797-817.
- Bisard, W. J., Arons, R. H., Francek, M. A., & Nelson, B. D. (1994). Assessing selected physical science and earth science misconceptions of middle school through university preservice teachers: Breaking the science "Misconception Cycle". *Journal of College Science Teaching*, 24, 38-42.
- Boeije, H. (2002). A purposeful approach to the constant comparative method in the analysis of qualitative interviews. *Quality & Quantity*, 36, 391-409.

- Bozdin, A. (2002). *Teaching science methods courses with web-enhanced activities*. Paper presented at the Annual International Conference of the Association for the Education of Teachers in Science, Charlotte, NC.
- Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18(1), 32-42.
- Calik, M., & Ayas, A. (2005). A comparison of level of understanding of eight-grade students and science student teachers related to selected chemistry concepts. *Journal of Research in Science Teaching*, (42), 6, 638-667.
- Caravita, S., & Hallden, O. (1994). Re-framing the problem of conceptual change. *Learning and Instruction*, 4, 89-111.
- Carey, S. (1988). Reorganization of knowledge in the course of acquisition. In S. Stratus (Ed.), *Ontogeny, phylogeny, and historical development* (pp. 1-27). New Jersey: Ablex Publishing Corporation.
- Carey, S. (1994). Domain-specific knowledge and conceptual change. In L. A. Hirschfeld & S. A. Gelman (Eds.), *Mapping the mind* (pp. 168-200). New York: Cambridge University Press.
- Charmaz, K. (1983). The grounded theory method: An explication and interpretation. In R. M. Emerson (Ed.), *Contemporary field research: A collection of readings* (pp. 109-126). Boston: Little Brown.
- Charmaz, K. (2000). Grounded theory: Objectivist and constructivist methods. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 509-536). London: Sage Publications.
- Chi, M. T. H., & Roscoe, R. D. (2002). The processes and challenges of conceptual change. In M. Limon & L. Mason (Eds.), *Reconsidering conceptual change: Issues in theory and practice* (pp. 3-29). Dordrecht, Netherlands: Kluwer Academic Publisher.
- Chi, M. T. H., & Slotta, J. D. (1993). The ontological coherence of intuitive physics. *Cognition and Instruction*, 10(2&3), 249-260.
- Chi, M. T. H., Slotta, J. D., & Leeuw, N. (1994). From things to processes: A theory of conceptual change for learning science concepts. *Learning and Instruction*, 4, 27-43.
- Chinn, C. A., & Brewer, W. F. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science teaching. *Review of Educational Research*, 63(1), 1-49.

- Clement, J. (1993). Using bridges analogies and anchoring intuitions to deal with student's preconception in physics. *Journal of Research in Science Teaching*, 30(10), 1241-1257.
- Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*, 20, 37-46.
- Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2<sup>nd</sup> Ed.). Hillsdale, NJ: Lawrence Erlbaum.
- Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches* (2nd ed.). Thousand Oaks: Sage Publications.
- diSessa, A. A. (1988). Knowledge in pieces. In G. Forman & P. B. Pufall (Eds.), *Constructivism in the computer age* (pp. 49-70). Hillsdale, NJ: Lawrence Erlbaum.
- diSessa, A. A. (1993). Toward an epistemology of physics. *Cognition and Instruction*, 10(2&3), 105-225.
- diSessa, A. A. (2002). Why "conceptual ecology" is a good idea. In M. Limon & L. Mason (Eds.), *Reconsidering conceptual change: Issues in theory and practice* (pp. 29-61). Dordrecht, Netherlands: Kluwer Academic Publisher.
- diSessa, A. A., & Sherin, B. L. (1998). What changes in conceptual change? *International Journal of Science Education*, 20(10), 1155-1191.
- Driver, R. (1989). Student's conceptions and learning of science. *International Journal of Science Education*, 11(Special Issue), 481-190.
- Duit, R. (1991). On the role of analogies and metaphors in learning science. *Science Education*, 75, 649-672.
- Duit, R. (1999). Conceptual change approach in science education. In W. Schnotz, S. Vosniadou & M. Carretero (Eds.), *New perspectives on conceptual change*. Oxford, UK: Elsevier Science Ltd.
- Duit, R., Roth, W.-M., Komorek, M., & Wilbers, J. (2001). Fostering conceptual change by analogies-between Scylla and Charybdis. *Learning and Instruction*, 11, 283-303.
- Duschl, R. A., & Gitomer, D. H. (1991). Epistemological perspectives on conceptual change: Implications for educational practice. *Journal of Research in Science Teaching*, 28, 839-858.

- Duxbury, A. C., & Duxbury, A. B. (1994). *An introduction to the World's oceans* (4th ed.). Oxford, England: Wm. C. Brown Publisher.
- Easton, K. L., McComish, J. F., & Greenberg, R. (2000). Avoiding common pitfalls in qualitative data collection and transcription *Qualitative Health Research, 10*(5), 703-707.
- Edelson, D. C. (2001). Learning-for-use: A framework for the design of technology-supported inquiry activities. *Journal of Research in Science Teaching, 38*(3), 355-385.
- Etkina, E., Matilsky, T., & Lawrence, M. (2003). Pushing to the edge: Rutgers astrophysics institute motivates talented high school students. *Journal of Research in Science Teaching, 40*(10), 958-985.
- Ferguson, G.A., (1966). *Statistical analysis in psychology and education*. New York: McGraw-Hill Book Company.
- Galili, I., & Lehavi, Y. (2003). The importance of weightlessness and tides in teaching gravity. *American Journal of Physics, 71*(11), 1127-1135.
- Gay, L. R. (1996). *Educational research: Competencies for analysis and application* (5th ed.). Upper Saddle River, NJ: Prentice-Hall.
- Georghiades, P. (2000). Beyond conceptual change learning in science education: Focusing on transfer, durability, and metalearning. *Educational Research, 42*, 119-139.
- Gilbert, J. K., Osborne, J., & Fensham, P. (1982). Children's science and its consequences for teaching. *Science Education, 66*(4), 623-633.
- Glaser, B. G. (1965). The constant comparative method of qualitative analysis. *Social Problems, 12*, 436-445.
- Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory*. Hawthorne, NY: Aldine.
- Glesne, C. (1999). *Becoming qualitative researchers: An introduction*. NY: Longman.
- Hartel, H. (2000). The tides-a neglected topic. *Physics Education, 35*(1), 40-45.
- Hewson, P. W. (1981). A conceptual change approach to learning science. *European Journal of Science Education, 3*(4), 383-396.

- Hewson, P. W. (1982). A case study of conceptual change in special relativity: The influence of prior knowledge in learning. *European Journal of Science Education*, 4(1), 61-78.
- Hewson, P. W., & Hennessey, G. (1992). Making status explicit: A case study of conceptual change. In R. Duit, F. Goldberg & H. Niedderer (Eds.), *Research in physics learning: Theoretical issues and empirical studies* (pp. 177-187). Kiel, Germany: Institute for Science Education at the University of Kiel.
- Hewson, P. W., & Hewson, M. G. A. B. (1984). The role of conceptual conflict in conceptual change and the design of science instruction. *Instructional Science*, 13(1), 1.
- Hewson, P. W., & Lemberger, J. (2000). Status as the hallmark of conceptual learning. In R. Millar, J. Leach & J. Osborne (Eds.), *Improving science education: The contribution of research*. Buckingham, Philadelphia: Open University Press.
- Hewson, P. W., & Thorley, N. R. (1989). The conditions of conceptual change in the classroom. *International Journal of Science Education*, 11(Special issue), 541-553.
- Hoffman, J. L., Wu, H.-K., Krajcik, J. S., & Soloway, E. (2003). The nature of middle school learner's science content understandings with the use of on-line resources. *Journal of Research in Science Teaching*, 40(3), 323-346.
- Ioannides, C., & Vosniadou, S. (2001). The changing meanings of force. *Cognitive Science Quarterly*, 2(1), 5-62.
- Ivarsson, J., Schoultz, J., & Saljo, R. (2002). Map reading versus mind reading: Revisiting children understanding of the shape of the earth. In M. Limon & L. Mason (Eds.), *Reconsidering conceptual change: Issues in theory and practice*. Dordrecht London: Kluwer Academic Publishing.
- Keating, T., Barnett, M., Barab, S. A., & Hay, K. E. (2002). The virtual solar system project: Developing conceptual understanding of astronomical concepts through building three-dimensional computational models. *Journal of Science Education and Technology*, 11(3), 261-275.
- Knauss, J. A. (1978). *Introduction to physical oceanography*. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.
- Krajcik, J., Marx, R., Blumenfeld, P., Soloway, E., & Fishman, B. (2000). *Inquiry-based science supported by technology: Achievement among urban school students*. Paper presented at the AERA.

- Krajcik, J. S., Simmons, P. S., & Lunetta, V. N. (1988). A research strategy for the dynamic study of students concepts and problem solving strategies using science software. *Journal of Research in Science Teaching*, 25(2), 147-155.
- Krippendorff, K. (2004). Reliability in content analysis: Some common misconceptions and recommendations. *Human Communication Research*, 30(3), 411-433.
- Kuhn, T. (1970). *The structure of scientific revolutions*. Chicago: University of Chicago Press.
- Kuiper, E., Volman, M., & Terwel, J. (2005). The web as an information resource in K-12 education: Strategies for supporting students in searching and processing information. *Review of Educational Research*, 75(3), 285-328.
- Lakatos, I. (1970). Falsification and the methodology of scientific research programs. In I. M. Lakatos, A. (Ed.), *Criticism and the growth of scientific knowledge* (pp. 91-196). Cambridge: Cambridge University Press.
- Lee, H.-S., & Songer, N. B. (2003). Making authentic science accessible to students. *International Journal of Science Education*, 25(8), 923-948.
- Limon, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: A critical appraisal. *Learning and Instruction*, 11, 357-380.
- Lin, C.-y., Cheng, Y.-j., Chang, Y.-t., & Hu, R. (2002). The use of internet-based learning in biology. *Innovations in Education and Teaching International*, 39(3), 237-242.
- Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage Publications.
- Lombard, M., Snyder-Duch, J., & Bracken, C. C. (2002). Content analysis in mass communication: Assessment and reporting of intercoder reliability. *Human Communication Research*, 28(4), 587-604.
- Mali, G. B., & Howe, A. (1979). Development of Earth and gravity concept among Nepali children. *Science Education*, 63(5), 685-691.
- Mayer, R. E. (2002). Understanding conceptual change: A commentary. In *Reconsidering conceptual change: Issues in theory and practice* (pp. 101-111). Dordrecht London: Kluwer Academic Publishing.
- Moore, C. J., & Huber, R. (2001). Internet tools for facilitating inquiry. *Contemporary Issues in Technology and Teacher Education*, 1(4), 451-464.

- Mortimer, E. F. (1995). Conceptual change or conceptual profile change. *Science & Education, 4*(267-285).
- Ng, W., & Gunstone, R. (2002). Students' perceptions of the effectiveness of the World Wide Web as a research and teaching tool in science learning. *Research in Science Education, 32*, 459-510.
- National Research Council (1996). *The national science education standards*. Washington, DC: National Academy Press.
- National Research Council (2000). *Inquiry and the national science education standards*. Washington, DC: National Academy Press.
- Nussbaum, J. (1979). Children conception of the earth as a cosmic body: A cross age study. *Science Education, 63*, 83-93.
- Nussbaum, J. (1989). Classroom conceptual change: Philosophical perspectives. *International Journal of Science Education, 11*(Special Issue), 530-540.
- Nussbaum, J., & Novick, S. (1982). Alternative frameworks, conceptual conflict and accommodation: Toward a principled teaching strategy. *Instructional Science, 11*, 183-200.
- Pfundt, H., & Duit, R. (1988). *Bibliography: Students' alternative frameworks and science education* (2nd ed.). Kiel, Germany: University of Kiel Institute for Science Education.
- Piaget, J. (1964). Development and learning. *Journal of Research in Science Teaching, 2*(3), 176-186.
- Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*(2), 167-199.
- Pond, S., & Pickard, G. (1983). *Introductory dynamical oceanography* (2nd ed.). Elmsford, NY: Pergamon Press Inc.
- Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*(2), 211-227.
- Post-Zwicker, A. P., Davis, W., Grip, R., McKay, M., Pfaff, R., & Stotler, D. P. (1999). Teaching contemporary physics topics using real-time data obtained via the World Wide Web. *Journal of Science Education and Technology, 8*(4), 273-281.

- Schoultz, J., Saljo, R., & Wyndhamn, J. (2001). Heavenly talk: Discursive, artifacts, and children's understanding of elementary astronomy. *Human Development, 44*, 103-118.
- Skam, K. (1994). Determining misconceptions about astronomy. *Australian Science Teachers Journal, 40*(3), 63-67.
- Skamp, K. (1994). Determining misconceptions about astronomy. *Australian Science Teachers Journal, 40*(3), 63-67.
- Slotta, J. D., Chi, M. T. H., & Joram, E. (1995). Assessing student' misconceptions of physics concepts: An ontological basis for conceptual change. *Cognition and Instruction, 13*(3), 373-400.
- Sneider, C. I., & Pulos, S. (1983). Children's cosmographies: Understanding the Earth's shape and gravity. *Science Education, 67*(2), 205.
- Songer, N. B. (1996). Exploring learning opportunities in coordinated network-enhanced classrooms: A case of kids as global scientist. *The Journal of the Learning Sciences, 5*(4), 297-327.
- Songer, N. B. (1998). Can technology bring students closer to science? In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 333-347). Great Britain: Kluwer Academic Publisher.
- Songer, N. B., Lee, H.-S., & Kam, R. (2002). Technology-rich inquiry science in urban classrooms: What are the barriers to inquiry pedagogy? *Journal of Research in Science Teaching, 39*(2), 128-150.
- Strauss, A. L., & Corbin, J. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage.
- Strike, K. A., & Posner, G. J. (1992). A revisionist theory of conceptual change. In R. A. Duschl & R. J. Hamilton (Eds.), *Philosophy of science, cognitive psychology, and educational theory and practice*. Albany, NY: State University Press of New York.
- Taylor, I., Barker, M., & Jones, A. (2003). Promoting mental model building in astronomy education. *International Journal of Science Education, 25*(10), 1205-1225.
- Team, O. U. C. (1989). *Waves, tides, and shallow-water processes*. Oxford: Pergamon Press Inc.

- Thagard, P. (1991). Concepts and conceptual change. In J. H. Fetzer (Ed.), *Epistemology and cognition* (pp. 101-120). Dordrecht, Boston, London: Kluwer Academic Publishing.
- Thagard, P. (1992). Analogy, explanation, and education. *Journal of Research in Science Teaching*, 29(6), 537-544.
- Thorndike, R. M. (1997). *Measurement and evaluation in psychology and education* (6th ed.). Upper Sadler River, NJ: Prentice-Hall.
- Thurman, H. V. (1993). *Essentials of oceanography* (4th ed.). New York, NY: Macmillan Publishing Company.
- Toulmin, S. (1972). *Human understanding*. Princeton: Princeton University Press.
- Treagust, D. F., Harrison, A. G., & Venville, G. J. (1996). Using an analogical teaching approach to engender conceptual change. *International Journal of Science Education*, 18(2), 213-229.
- Trundle, C. K. (in press). Acquiring on-line data for scientific analysis. In R. L. Bell, J. Gess-Newsome & J. Luft (Eds.), *National science foundation series: Technology in secondary science classrooms* (pp. TBA). Arlington, VA: National Science Foundation.
- Trundle, K. C., Atwood, R. K., & Christopher, J. E. (2002). Preservice elementary teachers' conceptions of moon phases before and after instruction. *Journal of Research in Science Teaching*, 39(7), 633-655.
- Trundle, K. C., & Bell, R. L. (2005). *The use of a computer simulation to promote scientific conceptions of moon phases*. Paper presented at the National Association of Research in Science Teaching, Dallas, TX.
- Trundle, K. C., & Krissek, L. A. (2005). Discovering tidal patterns. In R. L. Bell & J. Garofale (Eds.), *Science units for grade 9-12* (p. 159-175). Eugene, OR: ISTE.
- Tyson, L. M., Venville, G. J., Harrison, A. G., & Treagust, D. F. (1997). A multidimensional framework for interpreting conceptual change events in the classroom. *Science Education*, 81, 387-404.
- Ucar, S., Trundle, K.C., & Krissek, L. (2006). *Preservice teachers' understanding of standard-based Earth science content for grades K-4*. Paper Presented at Association for the Science Teachers Education, Portland, OR.
- Venville, G. J., & Treagust, D. F. (1996). The role of analogies in promoting conceptual change in biology. *Instructional Science*, 24, 295-320.

- Venville, G. J., & Treagust, D. F. (1998). Exploring conceptual change in genetics using a multidimensional interpretive framework. *Journal of Research in Science Teaching*, 35(9), 1031-1055.
- Viiri, J. (2000a). Students' understanding of tides. *Physics Education*, 35(2), 105-110.
- Viiri, J. (2000b). *Educational reconstruction of tides*. University of Joensuu, Finland. Publications in Education, 59 (in Finish).
- Viiri, J., & Saari, H. (2004). Research-based teaching unit on the tides. *International Journal of Science Education*, 26(4), 463-481.
- Vosniadou, S. (1991). Designing curricula for conceptual restructuring: Lessons from the study of knowledge acquisition in astronomy. *Journal of Curriculum Studies*, 23(3), 219-237.
- Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction*, 4, 45-69.
- Vosniadou, S. (1999). Conceptual change research: State of the art and future directions. In W. Schnotz, S. Vosniadou & M. Carretero (Eds.), *New perspectives on conceptual change* (pp. 3-15). Oxford, U.K: Elsevier Science Publishers.
- Vosniadou, S. (2001a). Designing learning environments to promote conceptual change in science. *Learning and Instruction*, 11(4-5), 381-419.
- Vosniadou, S. (2001b). What can persuasion research tell us about conceptual change that we did not already know. *International Journal of Educational Research*, 35(7-8), 731-737.
- Vosniadou, S., & Brewer, W. F. (1987). Theories of knowledge restructuring in development. *Review of Educational Research*, 57(1), 51-67.
- Vosniadou, S., & Brewer, W. F. (1992). Mental models of the Earth: A Study of conceptual change in childhood. *Cognitive Psychology*, 24(4), 535-585.
- Vosniadou, S., & Brewer, W. F. (1994). Mental models of the day/night cycle. *Cognitive Science*, 18, 123-183.
- Vosniadou, S., & Ioannides, C. (1998). From conceptual development to science education: A psychological point of view. *International Journal of Educational Research*, 20(10), 1213-1230.

- Vosniadou, S., & Kolloas, V. (2003). Using collaborative, computer-supported, model building to promote conceptual change in science. In E. De Corte, L. Verschaffel, N. Entwistel & J. Van Merriënboer (Eds.), *Powerful learning environments: Unraveling basic components and dimensions. Advances in learning and instruction*. Oxford, UK: Elsevier Press.
- Wallace, R. M., Kupperman, J., & Krajcik, J. (2000). Science on the web: Students online in a sixth-grade classroom. *The Journal of the Learning Sciences*, 9(1), 75-104.
- Wandersee, J. H., Mintzes, J. J., & Novak, J. D. (1994). Research on alternative conceptions in science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning*. NY: McMillan Publishing Company.
- White, R. T., & Gunstone, R. F. (1989). Metalearning and conceptual change. *International Journal of Science Education*, 11 (Special Issue), 577-586.
- Windschitl, M. (1998). Independent student inquiry: Unlocking the resources of the World Wide Web. *NASSP Bulletin*, 82, 93-98.
- Windschitl, M., & Irby, J. (1999). Tapping the resources of the world wide web for inquiry in middle schools. *Middle School Journal*, 40-46.
- Wiser, M., & Carey, S. (1983). When heat and temperature were one. In D. Gentner & A. L. Steven (Eds.), *Mental models* (pp. 267-297). Hillsdale, New Jersey: Lawrence Erlbaum.

APPENDIX A  
INTERVIEW PROTOCOL

## Interview Questions

### Introduction

1. Have you ever heard about tides?
  - a. Can you tell me where you heard it?
2. Have you been to the coast and seen effects of tides?
3. Can you tell me what you know about tides? (Probe in the direction of student's answers).
4. What do you think causes the tides? (Probe in the direction of student's answers)
5. Imagine that you are an astronaut and traveling in a space rocket around the Earth.

At some point you have looked at the Earth and you recognized the tides.

- a. From an astronaut perspective, draw what you would see of the Earth and label the picture with your explanation.

### Questions

1. You probably have heard or seen that the water level on the ocean can (ebb and flood) rise and fall at certain time of the days. We call these events tides high and low tides. What do you think causes the high and low tides?
  - If students shows any of the alternative models of the Earth (such as, disk, dual, hollow, Earth), probe the children explain their own shape of the Earth model.

PROVIDE THE MODEL: (The model is introduced to the students if they mention about the Earth, moon , and sun and following sentence will be read to student) These models represent the sun, Earth, and moon. For practical reasons, they are not to scale in size or

relative distances from each others. I want you to use this model to explain to me, and show me while you are explaining what you think causes; the high tides/low tides/neap tides/spring tides.

a. Could you tell me what high tide is?

(If student mentions about Earth, moon and sun, ask student to show it with model.)

b. Could you tell what low tide is?

(If student mentions about Earth, moon and sun, ask student to show it with model.)

2. Two times a month we have what we call spring tides. These are times when the high tides are very high and the low tides are very low. Do you know what causes spring tides?

- If you know what spring tides are, take the model and arrange it so that we would experience a spring tide.

3. Two times a month we have what we call neap tides. These are times when the difference between high and low tides is the smallest. Do you know what causes neap tides?

- If you know what the neap tides are, take the model and arrange it so that we would experience a spring tide.

4. Suppose that the moon had an ocean and continents on it. Would there be tides on the moon? If yes why there would be tides on the moon? If not, why not?

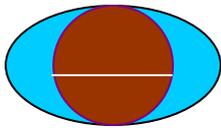
5. If it is high tide on one side of the Earth, facing the moon, what is happening on the other side of the Earth which is not facing the moon?

6. Why tides occur twice a day in the same place?

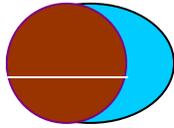
7. Do you agree with the following statements? Why or why not?

“Tides occurs only on the oceans”

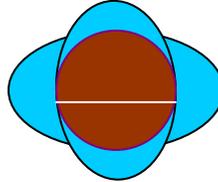
8. Which representations accurately symbolize an astronaut view of Earth and tidal bulges? (Earth in the middle (brown) and an exaggerated water level of the ocean (blue) around the Earth. White line represents the equator.)



A



B



C

None of these

E

Based on the drawing you selected, where would the sun and moon would be? Arrange with your model.

APPENDIX B  
TIDES ACHIEVEMENT TEST QUESTIONS



## B. Gravity

1. \*\*What is gravity?

---

2. Gravitational force between objects

- a. decrease when the objects gets closer
- b. increase when the objects gets closer
- c. increase when the objects gets farther form each other.
- d. does not change with distance between objects.
- e. Other.....

3. When people walked on the moon, they found that they could jump higher than they could back on Earth. Why is this true?

- a. There is no atmosphere on the moon
- b. The moon exerts less gravitational force than Earth
- c. Space suits helped them jump
- d. The moon rotates faster than Earth does
- e. Other.....

4. The force of gravity between two objects is greatest when....

- a. masses are small and the objects are close together
- b. masses are small and the objects are far apart
- c. masses are large and the objects are close together
- d. masses are large and the objects are far apart.
- e. Other.....

5. Does moon exert a gravitational force on Earth?

- a. Yes, and moon's gravitational force on Earth is less than that of Earth on moon.
- b. Yes, and moon's gravitational force on Earth is more than that of Earth on moon.
- c. Yes, and moon's gravitational force on Earth is equal to that of Earth on moon.
- d. No, moon does not exert a gravitational force on Earth.
- e. Other.....

6. Why is the gravitational attraction of the moon a greater factor in determining tides than the gravitational attraction of the much larger sun?

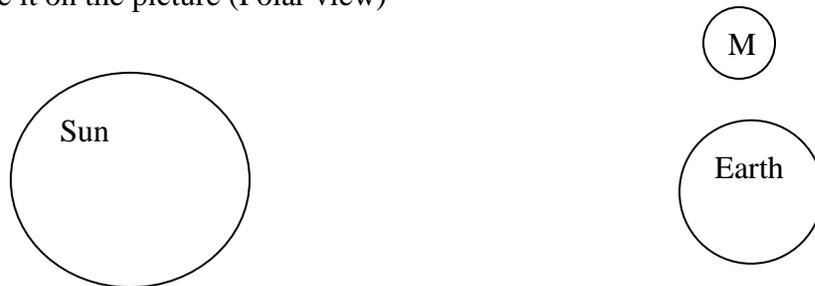
- a. Earth is much closer to the moon than to the sun
- b. the sun's gravity is a factor only during the day
- c. the moon's core has a much greater density than the sun's core
- d. the sun's mass is smaller than the mass of the moon
- e. Other.....

C. Tides

1. Where do the highest (and lowest) tides on Earth occur on the diagram below?  
Write it on the picture (Polar view)



2. Where do the highest (and lowest) tides on Earth occur on the diagram below?  
Write it on the picture (Polar view)



3. The side of the Earth that faces the moon experiences a high tide. At the same time, the side of the Earth that is opposite from the moon will have a(n):
  - a. high tide
  - b. low tide
  - c. neap tide
  - d. spring tide
  - e. Other.....
4. Which of these causes tides on the Earth?
  - a. The gravitational pull of the moon and sun
  - b. The revolution of the Earth around the sun
  - c. Differences in wind speed around the Earth
  - d. The tilt of the Earth's axis
  - e. Other.....
5. Spring tides are associated with
  - a. full moon only
  - b. first-and third-quarter moons
  - c. new and full moon
  - d. lunar eclipse
  - e. Other.....
6. Ocean tides are best described as
  - a. unpredictable and cyclic
  - b. unpredictable and noncyclic
  - c. predictable and cyclic
  - d. predictable and noncyclic

7. Spring tide occurs about:
  - a. once per month
  - b. once per season.
  - c. once per year.
  - d. twice per month.
  - e. twice per year.
  - f. Other.....
8. Neap tides occur:
  - a. at summer and winter solstice.
  - b. during a storm surge.
  - c. when the moon is full or new.
  - d. when the moon is at its first and third quarter.
  - e. when the sun is at perihelion or aphelion.
  - f. Other.....
9. \*\*The period of a diurnal tide is
  - a. 12 hours.
  - b. 24 hours 50 minutes.
  - c. 12 hours 50 minutes.
  - d. 12 hours 25 minutes.
  - e. 24 hours.
  - f. other.....
10. \*High tide is
  - a. only on the side of Earth facing the Moon
  - b. only on the side of Earth which is farthest from the Moon
  - c. both on the side of the Earth which is nearest and farthest of the Moon
  - d. somewhere else. Where:.....
11. \*\*An area that experiences semidiurnal tides will have:
  - a. one high tide and one low tide daily.
  - b. one high tide and two low tides daily.
  - c. one low tide and two high tides daily.
  - d. two high tides and two low tides of nearly equal height daily.
  - e. two unequal low and high tides daily.
  - f. other.....
12. \*High tide occurs in a specific area
  - a. about every 12 hours
  - b. about every 24 hours
  - c. about once a month
  - d. other way, how.....

(\* These questions adopted from Viiri (2000b) with his permission)

(\*\*These questions were deleted for the reliability analysis)

APPENDIX C  
JOURNAL ENTRIES

*Journal*

Please answer the following questions in the space provided. You are free to express your thoughts with drawing, writing, or both for each question.

\*What did you learn today? Write and/or draw a brief summary.

\*Did you ever feel confused today? If yes, what confused you?

\*How did you like best about what we did today? Why?

\*How did you like least about what we did today? Why?