The Pluto debate: Influence of emotions on belief, attitude, and knowledge change

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THE PLUTO DEBATE: INFLUENCE OF EMOTIONS ON BELIEF, ATTITUDE, AND KNOWLEDGE CHANGE

by

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University of Utah
2000

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A dissertation submitted in partial fulfillment of the requirements for the

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ABSTRACT

The Pluto Debate: Influence of Emotions on Belief, Attitude, and Knowledge Change

By

Suzanne H. Broughton

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In line with the “warming trend” (Sinatra, 2005), this study examined the influence of emotions during controversial conceptual change. Issues in science may trigger highly emotional responses (e.g., evolutionary theory). However, it is unclear whether these emotions facilitate or inhibit change.

I investigated the nature of emotions engendered when learning about a controversial science topic, Pluto's reclassification, including the valence (positive/negative) and activation (activating/deactivating) of emotions (Pekrun et al., 2002). I also investigated whether belief, attitude, and/or conceptual change could be facilitated through rereading a refutation text and/or rereading during small group discussions. Refutation texts directly state a common misconception, refute it, and provide the scientific explanation as a plausible alternative (Hynd, 2001). Participants were randomly assigned to a group (reread text; reread text plus small group discussions). Participants in both groups read the same refutational text regarding the recent change in the definition of planet and Pluto's reclassification.
The findings show that students’ experienced a range of emotions towards Pluto’s reclassification. Students reported experiencing more negative than positive emotions. Both positive and negative emotions were shown to be predictive of student’s attitudes and attitude change. Emotions were also predictive of students’ knowledge of planets and conceptual change. This suggests that emotions may have promoted deep engagement and critical thinking. Negative emotions may also be linked with resistance to attitude and conceptual change.

The refutation text was effective in promoting belief change, attitude change, and conceptual change across both conditions. Students in both conditions reported more constructivist nature of science beliefs after rereading the text. Students also reported a greater level of acceptance about Pluto’s reclassification. Conceptual change was promoted through the text as students’ initial misconceptions about why scientists rewrote the definition of planet. Students in the reread plus discussion group showed greater conceptual change regarding the reasons for rewriting the definition of planet than those in the reread group.

This study supports the “warming trend” (Sinatra, 2005) in conceptual change research because it shows the interplay between emotions and the change process. The findings also suggest that belief, attitude, and conceptual change can be fostered through small group discussions.
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CHAPTER 1

INTRODUCTION

It is often the case that issues in science trigger highly emotional responses. For example, global warming, evolutionary theory, and stem cell research are each considered “hot” topics in science. Recently, the change in the definition of what constitutes a planet in our Solar System sparked a heated debate among many scientists, astronomers, as well as many adults and school children in the public-at-large. Learning about such “hot” science topics in school can spark highly emotional reactions.

Children form conceptions about scientific phenomena through their everyday life experiences which often contradict accepted scientific explanations (Vosniadou & Brewer, 1987, 1992). For example, young children may hold a naïve conception of the earth as flat with people living on the surface and solar objects located above it (Vosniadou, 2003). The process of conceptual change is likely to begin when the formal scientific explanation is presented which commonly creates cognitive dissonance for the individual who holds conflicting beliefs (Dole & Sinatra, 1998; Hynd 2003; Posner, Strike, Hewson, & Gertzog, 1982).

The processes of knowledge and belief revision include an affective component (Pintrich, Marx, & Boyle, 1993; Linnenbrink & Pintrich, 2004; Sinatra & Pintrich, 2003, Gregoire, 2003). It may be the case that the scientific explanation triggers emotional
responses which in turn can facilitate or impede conceptual change. Researchers from social psychology and educational psychology have studied the influence of emotions on cognitive processes (Bless, 2000; Fiedler, 2000; Pekrun, Goetz, Titz, & Perry, 2002). One area that has not yet been investigated is how emotions facilitate or impede learning about controversial topics in science.

The purpose of the present study was to examine the influence of emotions on conceptual change, belief change, and attitude change when learning about a controversial topic: specifically the reclassification of Pluto to a dwarf-planet as a result of the revision of astronomers' definition of a planet (International Astronomical Union, 2006). Fifth and sixth grade students' emotions associated with the change in Pluto's status were assessed, as were their beliefs about the nature of science itself, and their conceptions about planets at pre-, post-, and delayed posttest.

The intervention for this study included a refutation text that addressed ideas about the changing nature of science (NOS) and information about the new definition of planets and the subsequent reclassification of Pluto to a dwarf-planet. The intervention also involved rereading the text (control group) or rereading along with small group discussions (experimental group) to facilitate engagement with the central ideas in the text.

Conceptual Change

Explanations of how the process of conceptual change occurs differ. For example, some researchers argue that conceptual change involves ontological category shifts (Chi, Slotta, & deLeeuw 1994) or the complete replacement of the concept with the
scientifically accepted explanation (Thagard, 1992). Others describe it as a developmental process whereby the individual gradually replaces naïve mental models with models more closely aligned with scientific views (Vosniadou, 1999; 2002; Vosniadou & Brewer, 1992).

Regardless of the process, most researchers agree that conceptual change is a gradual, time-consuming process (deLeeuw & Chi, 2003; Vosniadou, 2003; Sinatra, 2002). One possible explanation for this effortful cognitive process is that concepts are highly interdependent in their semantic (e.g., meaning) and syntactical (e.g., relationships between words) relations (Strike & Posner, 1992). According to Strike and Posner (1992), concepts are interdependent, rather than isolated, for their meaning. It may be the case that when one concept is reappraised for meaning, related concepts will also require reappraisal and possibly revision. Similarly, Vosniadou (2002) explains that conceptual change often involves the addition or deletion of beliefs during the process of reorganizing the framework theories in which the beliefs are embedded. Those concepts that are deeply embedded are most likely to be resistant to change (Chinn & Brewer, 1993).

Models of Conceptual Change

Historically, conceptual change was based on a theoretical model which viewed change as a purely cognitive process, involving four necessary conditions: dissatisfaction with existing conceptions and finding the new information to be intelligible, plausible, and fruitful (Posner et al., 1982). Pintrich, Marx, and Boyle (1993) challenged this “cold” view of conceptual change arguing instead for investigations on the role of affect, motivation, and situational factors of conceptual change. The Pintrich et al. (1993) article
has been influential in more recent models of conceptual change as they have included the role of affect, motivation, and situational factors.

For example, the Cognitive Reconstruction of Knowledge Model (CRKM) (Dole & Sinatra, 1998) acknowledges the role of affect as in the constructs of motivation and personal relevance. It can be argued that the stronger the emotional commitment the learner has to their prior conceptions, the less likely change will occur.

The Cognitive-Affective Model of Conceptual Change (CAMCC) (Grégoire, 2003), also describes the role of affect in the change process. Central to the CAMCC is the view that motivation and ability influence cognitive processing as well as the mediating role of cognitive processing on attitude change. Emotional responses to messages direct the level of engagement the individual has with the message.

Beliefs about the Nature of Science

The nature of science (NOS) has been described by some researchers as the assumptions and values inherent to scientific knowledge and its development (Khishfe & Abd-El-Khalick, 2001; Lederman, 1992; Lederman & Lederman, 2004). Central elements of NOS include the tentative nature of science knowledge, the role of observation, evidence derived through experimentation, and rational arguments in constructing scientific knowledge (Duit, Niedderer, & Schecker, 2007). These aspects of NOS have been emphasized in recent science education reform documents including Benchmarks for Science Literacy (AAAS, 1993).

For the present study, two of these characteristics were emphasized: the tentative nature of science knowledge and the justification and warrants for science knowledge.
The tentative nature of science was of importance to this study because students must understand that science knowledge is subject to change as new information challenges existing knowledge (AAAS, 1993) in order to understand a key element of the decision to change the definition of planet.

The second aspect of NOS selected for the present study was the justification and use of warrants in constructing scientific knowledge. Benchmarks emphasizes the importance of sixth grade students gaining an understanding that scientists make decisions based on claims that are supported by empirical evidence and confirmed with rational arguments (AAAS, 1993). This aspect was of value to the current study because a central argument presented in the refutation text was that scientists based their decision to change the definition of planet on the discovery of new objects in our solar system.

Attitude Change through Persuasion

*Elaboration Likelihood Model*

The Elaboration Likelihood Model (ELM) (Petty & Cacioppo, 1986) is a dual-process model that proposes two routes to change: the central route and the peripheral route. The central route is linked to deep cognitive processing of the message as the individual weighs its merits. In contrast, the peripheral route is associated with superficial processing where the individual is less likely to scrutinize the merits of the message. The ELM suggests that persuasion occurs in ways similar to conceptual change. Persuasion is more likely to occur through deep processing of the message.
**Persuasion**

Persuasion has been described as the process of facilitating a change in one’s understanding in relation to a specific idea or premise (Murphy, 2001). Persuasion has been described by several conceptual change researchers as the process of initiating a shift in an individual’s beliefs or understanding of a particular topic by fostering deep engagement through argument and reasoning (Alexander, Buehl, & Sperl, 2001; Hynd, 2003). The process of persuasion often occurs through the interaction between the individual and a text (Petty & Cacioppo, 1986). Some conceptual change researchers suggest that deep cognitive engagement with the message increases the likelihood of change (Buehl, Alexander, Murphy, & Sperl, 2001; Dole & Sinatra, 1998).

**Resistance to persuasion.** Resistance is the act of withstanding influence (Knowles & Linn, 2004). Individuals may resist change when their prior knowledge is deeply entrenched (Dole & Sinatra, 1998; Vosniadou & Brewer, 1992), if they are not dissatisfied with their existing conception, or if they do not find the new information plausible, intelligible, or fruitful (Posner et al., 1982). Resistance to persuasion may also occur when the topic is highly personally relevant or when the individual has high levels of background knowledge (Dole & Sinatra, 1998; Petty & Cacioppo, 1986; Pintrich et al., 1993). It may also be the case that when an individual is confronted with a message that explicitly and directly refutes their prior beliefs that they may reject the message altogether (Chinn & Brewer, 1993).
Emotions and Cognitive Processes

Researchers have asserted that affect and cognition are distinct but interdependent constructs (Lazarus, 1982; Zajonc, 1980). In addition, emotions are powerful influences on how we think and interpret events (Lazarus, 1984). Emotional responses are quick, automatic, and can occur unconsciously (Rosenberg, 1998).

Social psychologists have been exploring the relationship between affect and cognition and have demonstrated that mood congruency (i.e., improved recall of positive information in pleasant mood and negative information in an unpleasant mood) influences encoding, retrieval, and judgments (Fiedler, 2000; Forgas, 2000). In addition, positive affect is linked with top-down, heuristic processing strategies while negative affect is more commonly associated with bottom-up, detail-oriented, systematic processing (Bless, 2000). Heuristic processing has been described as “general strategies that might lead to the right answer” (Woolfolk, 2005). In other words, positive affect has been related to superficial rather than elaborative processing of information (Bless, 2000).

Forgas (2000) explains that heuristic processing is superficial and most often occurs when the task is relatively simple, typical, involves low levels of perceived personal relevance, or when motivation to engage in deeper cognitive processing is low. In these instances, responses to the information may be based on irrelevant or superficial associations. For example, heuristic processing may occur when an individual is contacted by a telephone pollster and asked to make quick judgments about an issue they have not given much thought to previously.
Academic Emotions

Pekrun, Goetz, Titz, and Perry (2002) explored the role of academic emotions which are domain-specific emotions related to classroom learning tasks. Academic emotions consist of two dimensions: valence (positive or negative) and activation (activating or deactivating). Positive activating emotions include enjoyment of learning, and hope for success; positive deactivating emotions are those which may inhibit learning such as relaxation after success and contentment. Negative activating emotions include anger and anxiety. Boredom and hopelessness are classified as negative deactivating emotions. It may be the case that students who experience activating emotions (positive or negative) in response to scientific explanation may be more successful in revising their existing conceptions because these emotions increase the likelihood of higher levels of cognitive engagement which in turn increases the likelihood of change (Dole & Sinatra, 1998). It may also be the case that negative emotions (activating or deactivating) may be associated with resistance to persuasion.

Emotions and Conceptual Change

Conceptual change involves an affective component which can include negative and positive emotions (Dole & Sinatra, 1998; Gregoire, 2003; Pintrich et al., 1993). Negative moods may increase the likelihood of deep cognitive processing of information (Bless, 2000; Forgas, 2000; Pekrun et al., 2002). Negative moods may also serve as cues, signaling inconsistencies between the individual’s prior knowledge and the information at hand (Limon, 2003). In addition, negative moods are associated with accommodation (Fiedler, 2000), which educational psychologists argue is the process through which conceptual change occurs (Dole & Sinatra, 1998; Gregoire, 2003; Posner et al., 1982).
However, negative emotions such as fear and anxiety may also lead to the individual perceiving the anomalous information as a threat and thus resist change (Linnenbrink & Pintrich, 2002; Gregoire, 2003).

Positive moods can also influence the change process. Change may be impeded if the individual experiences positive emotions such that they do not engage in message elaboration (Bless, Bohner, Schwarz, & Strack, 1990). However, positive emotions can facilitate the change process if the individual is able to recognize the inconsistency between their prior knowledge and the information presented to them. Bless (2000) argues that positive moods use less complex processing strategies until a discrepancy is noticed. Once the discrepancy is noticed, the individual is more likely to engage in deeper level processing of the conflicting information. It is possible that an individual who experiences positive emotional responses to anomalous information may be willing to give thoughtful consideration of that information even when it conflicts with their prior knowledge (Linnenbrink, 2006).

Research by Pekrun et al. (2002) suggests that positive activating emotions can induce critical thinking. Positive activating emotions such as enjoyment and hope have been shown to correlate positively with interest and motivation. In addition, positive activating emotions have been found to correlate positively with metacognitive strategies, critical thinking, and elaboration. Further research is needed to investigate whether the likelihood of conceptual change is increased as the result of the presence of positive activating emotions as linked with critical thinking skills.
Refutation Texts

Refutation texts use persuasive techniques to promote conceptual change (Hynd, 2001). Refutation texts are designed to elicit students' misconceptions about a phenomenon, refute them, and then present the scientific explanations as plausible and fruitful alternatives (Hynd, 2003; Mason & Gava, in press). Moreover, refutation texts have been found by researchers to be an effective tool for promoting conceptual change among students in science classrooms (Guzzetti et al., 1993; Hynd, Alvermann, & Qian, 1997; Hynd, McWhorter, Phares, & Suttles, 1994).

Facilitating Engagement with Refutation Texts

Group discussions provide the forum through which students can have the opportunity to share their ideas and listen to the ideas of others. Through this exchange of ideas, students can construct new conceptions and ways of thinking (Chinn, Anderson, & Waggoner, 2001). Small group literature discussions have been shown to facilitate engagement, increase comprehension, and promote critical analysis of the ideas presented in the text (Anderson et al., 1998; Beck & McKeown, 2001, 2006; Eeds & Wells, 1989; Raphael, 1998; McKeown, Beck, & Worthy, 1993). It is through these higher levels of cognitive engagement with the ideas in a text that the likelihood of conceptual change may occur (Dole & Sinatra, 1998).

Fostering Engagement through Small Group Literature Discussions

Questioning the Author (QtA) (Beck & McKeown, 2001, 2006; Beck, McKeown, Sandor, Kucan, & Worthy, 1996) is an instructional intervention for promoting deeper levels of cognitive engagement with ideas presented in texts. Engagement with the ideas is facilitated through collaborative discussions between teacher and students. The
collaborative meaning-making discussions take place as the teacher and students read the
text together, pausing at key points in the text to grapple with ideas in order to make
sense of the ideas presented. Questioning the Author provides students the opportunity to
connect their topic-relevant knowledge with what the author has written as well as to
what other students know, and then use that information in constructing a collaborative
understanding of the text (McKeown et al., 1993).

Purpose of Study

One goal of this study was to investigate the nature of emotions engendered when
learning about a controversial topic in science. Additional research is needed that
investigates the influence of the two dimensions of emotions (valence, activation)
(Pekrun et al., 2002) on controversial topics. Researchers have demonstrated that
emotions and cognition are highly interrelated (Bless, 2000; Fiedler, 2000; Forgas, 2000;
Lazarus, 1982, 1984; Zajonc, 1980) and that the conceptual change process has an
affective component (Linnenbrink & Pintrich, 2002; 2004). What is not yet understood is
how those two dimensions of emotions influence learning about a controversial topic in
science.

Using Pekrun et al. (2002) as a framework, this study examined the valence
(positive/negative) and activation (activating/deactivating) of emotions students
experienced and the influence those emotions may have exerted on the change process
while studying about the nature of science and Pluto’s dwarf-planet status.

A second goal of this study was to examine whether rereading a refutation text or
rereading a refutation text with small group discussions about the text would promote
change in students' beliefs, attitudes, and conceptions. According to the CRKM (Dole & Sinatra, 1998) higher levels of engagement with a message increases the likelihood of change. It may be that rereading the text increased cognitive engagement. Further, even deeper levels of engagement may have resulted from rereading and discussing the text.

Additionally, past research investigating students' NOS beliefs have used students' beliefs as a predictor of whether belief change is likely to occur (Mason, in press; 2001; Mason & Gava, in press). This study adds to the existing literature by investigating whether change in students' beliefs about the nature of science can be promoted through rereading the refutation text alone or rereading the text plus small group discussions.

In the first phase of this mixed methods study, quantitative data about students' NOS beliefs, students' attitudes towards the reclassification of Pluto, and students' emotions regarding Pluto's change in planetary status were measured. Qualitative data was collected during the small group discussions centered on the changing nature of science and Pluto's new status. This information was analyzed to see if student's responses moved toward a coherent representation of the central ideas presented in the text and whether belief change and/or attitude change occurred through the discussions. In the second phase, qualitative semi-structured interviews were used with four participants to explore the influence of emotions on controversial conceptual change. The reason for the qualitative follow-up data was to better understand the quantitative results from the first phase of the project.
Research Questions and Hypotheses

Three research questions guided this study:

1. What emotions are engendered among fifth and sixth grade students when learning about a controversial topic in science?

2. Do these emotions predict students’ a) beliefs about the nature of science and changes in those beliefs b) attitudes towards the reclassification of Pluto, c) and/or conceptual knowledge regarding concepts of planets? Do these emotions facilitate or inhibit change in students’ beliefs, attitudes, and/or conceptual knowledge about the reclassification of Pluto? Are negative activating emotions associated with greater entrenchment or greater change toward the accepted scientific view, or will it differ for different students?

3. Does enhancing the reading of a refutational text through small group discussions promote greater change than rereading in students’ a) beliefs, b) attitudes, and c) conceptual knowledge about planets?

For question 1, I hypothesized that students would experience a range of positive activating, negative activating, and negative deactivating emotions (Pekrun et al., 2002; 2006) in relation to Pluto’s reclassification.

For question 2, I hypothesized that positive emotions would be related to more constructivist NOS beliefs, positive attitudes towards Pluto’s reclassification, and more correct scientific knowledge of the planets and Pluto. It may be the case that students who understand the tentative nature of science knowledge and the role of new discoveries and evidence in informing what we know in science would have more positive emotions related to Pluto’s change. It is also likely that students who report positive emotions in
relation to Pluto's reclassification are also likely to agree with the scientist's decision. Positive emotions may also be related to more correct conceptual knowledge about the planets and Pluto because students who hold those scientific conceptions may also enjoy learning about the planets.

I expected to see negative emotions related to less constructivist NOS beliefs, disagreement with Pluto's reclassification, and misconceptions about the planets and Pluto. It is likely that students who do not understand the use of evidence and new discoveries in the development of scientific knowledge, as well as the changing nature of science, may experience negative emotions because this information may conflict with their prior beliefs. It is also plausible that students who reported feeling negative emotions were likely to reject the reclassification of Pluto because they were mad or frustrated with the decision. In addition, negative emotions may be linked with misconceptions about the planets and Pluto because individuals can become upset when the new information conflicts with their prior beliefs (Chinn & Brewer, 1982).

I predicted that positive activating emotions would be associated with higher levels of NOS belief change, greater acceptance of the change in Pluto's status, and greater degrees of conceptual change than negative activating or negative deactivating emotions.

More specifically, I expected to see a hierarchical effect of emotions linked with the degree of change in that positive activating emotions would be associated with the highest levels of change. Next, negative activating emotions would be associated with higher levels of change than negative deactivating emotions but not as much change as those associated with positive activating emotions. Lastly, negative deactivating emotions
would be linked with the smallest degree of change in students' NOS beliefs, attitudes about Pluto's reclassification, and conceptual knowledge about planets.

Past research suggests that positive emotions are associated with critical thinking skills when the individual notices a discrepancy between their current ideas and the new information (Bless, 2000; Bless, et al., 1990). It may be the case that students who experienced positive activating emotions in relation to Pluto's reclassification may have had high levels of engagement with the ideas presented in the text. As a result, students with positive activating emotions may have experienced the highest degree of change.

I expected that students who experienced negative activating emotions in relation to the change in Pluto's planetary status would also experience high levels of engagement with the text. Models of conceptual change (Dole & Sinatra, 1998; Gregoire, 2003) suggest that negative emotions associated with cognitive dissonance may facilitate engagement. Research in social psychology also reveals that negative emotions can promote elaboration (Bless et al., 1990) and top-down, detailed processing of information (Fiedler, 2000; Forgas, 2000). However, negative emotions may also increase resistance to change (Dole & Sinatra, 1998; Petty & Cacioppo, 1986; Pintrich et al., 1993). This may result in the individual rejecting the new information (Chinn & Brewer, 1993). Therefore, I hypothesized that negative activating emotions would result in some individuals becoming more deeply entrenched in their initial beliefs and attitudes while others may have experienced a change toward acceptance of the scientific view.

I also expected negative deactivating emotions, such as boredom, to be associated with the lowest levels of change. It may be the case that boredom does not facilitate
engagement with new ideas. Low levels of engagement decrease the likelihood of change (Dole & Sinatra, 1998).

For question 3, I hypothesized that students who reread the refutation text and engaged in small group discussions would experience greater levels of change in NOS beliefs, attitudes towards Pluto, and concepts about planets than students who reread the text. Past research has shown that engagement with text increases through small group discussions (Beck & McKeown, 2006; Beck et al., 1996; Chinn et al., 2001). This increased engagement with the ideas in the text may increase the likelihood of change (Dole & Sinatra, 1998) in students’ NOS beliefs, attitudes, and concepts about planets.

Method

The design of this study was a mixed between-within subjects repeated measures design that examined the role of emotions in NOS belief, attitude, and conceptual change. Time of test (pretest, posttest, and delayed posttest) was the within-subjects factor while condition (reread, reread plus discussion) was the between-subjects factor. I used both quantitative and qualitative data.

Participants

Participants for this study were fifth and sixth grade students enrolled in a private school located in the intermountain West. Students at this school came primarily from White, upper-middle class families. There were approximately the same number of males and females. Student’s ages ranged from 10 to 12 years old.

Measures
Students completed four instruments as pretest, posttest, and delayed posttest measures. These instruments included the Emotions about Pluto’s Reclassification survey (EPR), the Attitudes about Pluto survey, the Beliefs about the Nature of Science survey (Conley, et al., 2004), and the Concepts about Planets survey. The intervention for this study included a refutation text that explained the changing nature of science, the role of evidence in making scientific decisions, and the history of Pluto’s status as a planet. Additionally, the text includes information on the definition of a planet. Students in both condition groups read the text twice. The conditions for rereading the text varied between groups. The experimental group reread the text during small group QtA discussions. Students in the control group reread the text independently at their desks.

**Participant Interviews**

Eight interview questions assessed participants’ initial attitudes towards the reclassification of Pluto, initial emotional responses to the change in planetary status of Pluto, and their beliefs about the nature of science and conceptual knowledge about planets. Questions also addressed participants’ beliefs, attitudes and conceptual knowledge after having read the text.

**Procedure**

Data collection occurred over a two week period during 4 one-hour sessions per classroom. Within each classroom, students were randomly assigned to either the experimental group (reread text plus discussion) or the control group (reread only). In session one, students were asked to complete the following surveys: Emotions about Pluto (EPR), Demographics, Attitudes about Pluto, Concepts about Planets, and Beliefs about the Nature of Science.
Session two took place two days after session one. All students read the refutation text. Immediately following reading the text, students completed the EPR.

Session three took place one day after session two. Students in the experimental group reread the text while participating in a Questioning the Author (Beck, McKeown, Sandora, Kucan, & Worthy, 1996) style small group discussion. Students’ NOS beliefs, attitudes towards Pluto’s reclassification, and concepts about planets were elicited during the discussion. Students in the control group reread the text independently. At the conclusion of their respective activities, all students completed the EPR, Attitudes about Pluto Survey, Concepts about Planets Assessment, and Beliefs about the Nature of Science as posttests.

Session four occurred 14 days after session three. Students completed the Attitudes about Pluto Survey, Concepts about Planets Assessment, and Beliefs about the Nature of Science Survey as delayed posttests.

After completing an initial analysis of the data, four students were purposefully selected to participate in interviews. Two students from each class were selected based on those who experienced the greatest overall degree of change and those who experienced the least overall degree of change in their NOS beliefs, attitudes, and concepts. The purpose of these interviews was to further explore the influence of emotions on the change process of students’ NOS beliefs, attitudes towards Pluto’s reclassification, and concepts about planets.
Results

The results indicated that students experienced a range of emotions towards Pluto's reclassification. Students reported experiencing more negative than positive emotions. Both positive and negative emotions were shown to be predictive of students' attitudes and attitude change. Emotions were also predictive of students' knowledge of planets and conceptual change. These findings suggest that emotions may have fostered deep engagement and critical thinking. In addition, the results suggest that negative emotions may also be linked with resistance to attitude and conceptual change.

The refutation text was effective in promoting belief change, attitude change, and conceptual change across both conditions. Students in both conditions reported more constructivist NOS beliefs and a greater level of acceptance about Pluto's reclassification after rereading the text. Conceptual change was promoted through the text as students' initial misconceptions about why scientists rewrote the definition of planet. Students in the reread plus discussion group showed greater conceptual change regarding the reasons for rewriting the definition of planet than those in the reread group.

Limitations

One limitation for the present study is related to the participants. These students were primarily from White, upper-middle class families and they were enrolled in a private school. In addition, I had a relatively small sample size. Further research is warranted to investigate whether these findings would be replicated with larger sample sizes and different student populations.
A second limitation of this study is that the intervention was constrained by time. In the context of authentic science learning units, more time and instruction would be provided for students to engage with the discipline materials. Students may have experienced greater levels of change across the three constructs had they been given more opportunities to engage with the materials (Diakidoy et al., 2003).

A third limitation of this study was the time on task difference between the two groups. It is clear that students who reread the text independently at their desks had less time on task than those who participated in the small group discussions. In future studies, an additional task will be developed to better equalize the time on task between the experimental and control groups.

A fourth limitation to this study is in relation to the measuring of students’ emotions. I used self-report surveys based on measures developed by researchers in this field of study (Pekrun et al., 2002; 2005). The self-report measures used in this study captured students emotional responses as close to the moment as possible but not on-line and in the moment. Future research is needed to develop more effective ways of identifying student’s emotions as they occur.

Organization

The purpose of this study was to examine the influence of emotions when learning about a controversial topic in science. The topic of Pluto’s reclassification provided an avenue to explore the influence of emotions on student’s nature of science beliefs, attitudes, and conceptual change. I provide a brief overview of the theoretical framework and purpose of the study in Chapter One. In Chapter Two I provide a review
of the literature and the research questions. The methodology used in the present study, including a description of the measures, is given in Chapter Three. In Chapter Four I present the results of the study detailing both the quantitative and qualitative findings. I present a discussion of the study in Chapter Five including the theoretical significance and educational implications, as well as recommendations for future research.
CHAPTER 2

REVIEW OF RELATED LITERATURE

On August 24, 2006, the International Astronomical Union (IAU) General Assembly passed a resolution that changed the definition of "planet." The IAU agreed that "a planet is defined as a celestial body that is (a) in orbit around the Sun, (B) has sufficient mass for its self-gravity to overcome rigid body forces that that it assumes a hydrostatic equilibrium (nearly round) shape, and (c) has cleared the neighborhood around its orbit" (IAU, 2006). As a result, scientists now explain that the Solar System consists of eight planets: Mercury, Venus, Mars, Earth, Jupiter, Uranus, Saturn, and Neptune. Pluto was reclassified as a dwarf planet. This resolution was not supported by all members of the IAU. Indeed, according to Newsweek (2006) this decision has spawned an emotionally charged debate among members of the IAU and others who believe this decision was a mistake and are calling for an ad hoc conference to come up with yet another definition of planet as a way to restore Pluto's status as the ninth planet in our Solar System.

It is often the case that issues in science trigger highly emotional responses. Global warming, stem cell research, and genetically altered food could each be considered "hot" topics in science. Even the change in the definition of the term planet and the subsequent change in Pluto's status as a planet sparked a highly emotional debate among astronomers, scientists, and many individuals in the public at large (Newsweek, 2006; Fox News, 2006).

In similar ways, learning about certain scientific topics in school has the potential to spark strong emotions among students. This may especially be the case when students learn that scientists have changed an explanation of a phenomenon or a definition of an
object or event. Researchers have shown that students' nature of science (NOS) views often include the belief that scientific knowledge is absolute and unchanging (Khishfe & Abd-El-Khalick, 2002; McComas, 1998). Students who perceive science knowledge as absolute, and who are deeply committed to their beliefs about a particular topic, may experience strong emotional reactions when presented information that conflicts with their prior beliefs. Indeed, a professor of planetary science at the Massachusetts Institute of Technology who helped construct the new definition of planet explains, “The word ‘planet’ and the idea of planets can be emotional because they’re something we learn as children,” (Fox News, 2006).

Learning about Pluto’s reclassification as a dwarf planet likely involves change in conceptions about what constitutes a planet as well as change in beliefs about the nature of science and attitudes toward the reclassification. In this chapter I will present ways in which researchers have investigated the processes of conceptual change, belief change, and attitude change in the domain of science. Research from social psychology on persuasion is included in this discussion. In addition, research on emotions and cognition, as well as how emotions may influence learning, will be presented. A description of refutation texts, which have been shown to be effective in promoting conceptual change (Guzzetti, Snyder, Glass, & Gammas, 1993; Hynd, 2001) will be provided, including a review of how researchers have used refutation texts in conjunction with investigations of the influence of epistemological beliefs on conceptual change. Some researchers have suggested that the likelihood of change increases as the individual’s level of engagement with the text increases (Dole & Sinatra, 1998; Murphy, 2007; Petty & Cacioppo, 1986).
Therefore, the chapter will conclude with a description of three influential small group discussion techniques intended to increase engagement with texts.

Knowledge, Beliefs, and Attitudes

Prior to engaging in a discussion about how to change students’ conceptions, it is important to distinguish between knowledge, beliefs, and attitudes. Clearly defining knowledge and beliefs has been a challenge for philosophers and psychologists as far back in time as Plato (Murphy, 2007; Murphy & Mason, 2006). Indeed, making clear distinctions between knowledge and beliefs is avoided by most educational psychologists (Smith & Siegel, 2004; Southerland, Sinatra, & Matthews, 2001). Instead, researchers use either knowledge or beliefs, or use the terms interchangeably. Redefining these constructs is beyond the scope of this project. Instead, I will focus on definitions from science education and educational psychology with the goal of defining the constructs to be used in this research.

Southerland et al. (2001) use Plato’s account of knowledge as a framework to define knowledge as justified true beliefs. Educational psychologists have defined knowledge as factual, objective, must be supported with strong warrants, external verification, and confirmed by others who have interacted with the object as well (Alexander & Dochy, 1995; Murphy, 2007; Murphy & Mason, 2006). Knowledge requires external validation and is defined as acquired through formal schooling (Alexander & Dochy, 1995).

In contrast, beliefs require few warrants or may even be justified on warrants that are not accepted by the scientific community (Southerland et al., 2001). Beliefs are that
which a person accepts or hopes to be true (Murphy & Mason, 2006), and may be false
(Kardash & Scholes, 1996). Beliefs are a necessary but not a sufficient condition of
knowledge (Smith & Siegel, 2004), are formed through everyday experiences, are
subjective, and contain an affective component (Alexander & Dochy, 1995; Murphy,
2007). Knowledge and beliefs have been explained as overlapping constructs (Murphy &
Mason, 2006). However, in this research I use knowledge and beliefs as distinct
constructs based on these definitions.

Social psychologists define attitudes as the evaluative judgments that combine
cognitive and affective responses to an object (Crano & Prislin, 2006). Other definitions
suggest that attitudes are general evaluations consisting of cognitive beliefs, affect, and
actions that can influence cognition, affect, and behavior (Hynd, 2003; Petty & Cacioppo,
1986). According to Hynd, beliefs, affect, and behavior are interdependent and equally
influential. Based on this assertion, Hynd explains that attitude change can be considered
to be similar to conceptual change because they each include beliefs, affect and behavior.
For the present study I rely on Hynd's (2003) definition of attitudes in that attitudes
include cognitive beliefs, affect, and behavior that can influence cognition, affect, and
behavior.

Characterizations of Conceptual Change

Learning scientific concepts within the classroom setting often involves the
restructuring of students' naïve beliefs. Traditionally, researchers within the fields of
cognitive and educational psychology, as well as science educators refer to this
restructuring of knowledge as conceptual change (Chinn & Brewer, 1993; Dole &
Sinatra, 1998; Duit, 1999; Posner, Strike, Hewson, & Herzog, 1982; Vosniadou, 1999; Vosniadou & Brewer, 1987). It is hypothesized that the learner can play an active role in this process through internally-initiated, goal-directed cognitive processes (Sinatra & Pintrich, 2003).

Conceptual Change Foundations

Research in conceptual change is based upon constructivist approaches to learning (Posner et al., 1982). Predicated on Piaget's views of cognitive development, constructivist approaches share the view that the individual plays an active role in constructing knowledge as they interpret and learn about their environment (Duit, 1995). It is through this process of construction that individuals develop schemes, or the basic mental units that represent a class of similar thoughts or actions (Ormrod, 2004). New schemes are constructed and existing schemes are practiced and sometimes modified as the individual interacts with their environment.

As the individual interacts with their environment they integrate new information through one of two processes, assimilation or accommodation (Ormrod, 2004). Assimilation occurs when the individual uses their prior knowledge to understand the new information (Flavell, Miller, & Miller, 2002). According to Gredler (2005), assimilation is not a passive process of simply replicating the environment. Rather, the individual filters the information from the environment through their prior knowledge, thus enriching their prior knowledge.

In contrast, accommodation is the process of restructuring an existing scheme or forming a new scheme (Ormrod, 2004). Accommodation occurs when the individual realizes his or her prior knowledge conflicts with events in the environment, then acts to
reorganize those beliefs. It is the process of accommodation that sparked the interest of science educators to begin investigating the phenomenon of conceptual change (Posner et al., 1982).

Process of Conceptual Change

Explanations of how the process of conceptual change occurs differ. For example, some researchers argue that conceptual change is a radical restructuring of concepts involving ontological category shifts (Chi, Slotta, & deLeeuw 1994), the structuring of a complex knowledge system from fragments of naïve conceptions (diSessa & Sherin, 1998) or a complete replacement of the concept with the scientifically accepted explanation (Thagard, 1992). Conceptual change is also explained as a developmental process as the individual gradually replaces naïve mental models with models more closely aligned with scientific views (Vosniadou, 1999; 2002; Vosniadou & Brewer, 1992).

Regardless of the process, most researchers agree that conceptual change is a gradual, time-consuming process (Chi, in press; deLeeuw & Chi, 2003; Murphy, 2007; Vosniadou, 2003; Sinatra, 2002). Strike and Posner (1992) offer one possible explanation for this effortful cognitive process suggesting that concepts are highly interdependent in semantic and syntactical relations. Concepts are interdependent, rather than isolated, for their meaning. It may be the case that when once concept is reappraised for meaning, related concepts will also require reappraisal and perhaps revision.

Similarly, Vosniadou (2002; 2004) argues that conceptual change often involves the addition or deletion of beliefs during the process of reorganizing the framework theories in which the beliefs are embedded. Changing one concept means changing other
related concepts in a domino-like manner. Those concepts that are deeply embedded are most likely to be difficult to change (Chinn & Brewer, 1993). This may especially be the case for concepts that individuals formed from childhood that have been reinforced through everyday experiences (Vosniadou, 2003).

In contrast, Chi and Roscoe (2002) argue that mental models can be a coherent set of interrelated propositions. Conceptual change involves an ontological category shift of those beliefs. However, individuals may also hold a set of incoherent or fragmented ideas. When this occurs, the individual may be unaware that they lack a complete understanding of the phenomenon. As a result, they may not recognize a conflict with their prior knowledge when a scientific explanation is presented that contradicts that knowledge. Hence, Chi and Roscoe explain, “Misconceptions are difficult to change because students lack awareness of their misunderstanding, or they lack an alternative category to shift concepts into” (p. 25).

Over the past two decades researchers in science education and educational psychology have developed theoretical models in an attempt to explain the conceptual change process. In the following section, three seminal models of conceptual change will be discussed. These theoretical models include an affective component that will help to explain the role of emotions in controversial conceptual change learning.

Models of Conceptual Change

*Conceptual Change Model*

Posner and colleagues (1982) developed the Conceptual Change Model (CCM) in an attempt to understand why students’ prior beliefs are so resistant to change. They
based their theoretical model on the assumptions that learning is a rational endeavor and conceptual change would be similar to scientific revolutions in the science community. According to the CCM, knowledge restructuring occurs through either assimilation or accommodation. Assimilation represents a weak change in exiting concepts. In contrast, Posner et al. argued that through a process of accommodation the learners’ existing beliefs would undergo a radical restructuring or wholesale replacement.

According to the CCM, individuals must experience four conditions in order for conceptual change to occur. The individual must become dissatisfied with their existing beliefs, and deem the new conception intelligible, plausible, and fruitful. If one of these four factors is not met, it is unlikely that change will occur.

The CCM includes an affective component, though it is not explicitly addressed in the description of the model. The condition of dissatisfaction may trigger emotions that in turn induce deeper processing of the anomalous information to determine whether it is intelligible, plausible and fruitful. The CCM is based on rational inquiry and is considered a “cold” model of conceptual change (Pintrich, Marx, & Boyle, 1993). Conceptual change models developed after the CCM addressed the role of motivational and social factors as having more of a central role in conceptual change (Sinatra, 2005).

The remaining two theoretical models of conceptual change included in this discussion, the Cognitive Reconstruction of Knowledge Model (Dole & Sinatra, 1998) and The Cognitive-Affective Model of Conceptual Change (Gregoire, 2003), include an affective component in the change process. Each of these models will be described in the following section.
Cognitive Reconstruction of Knowledge Model

The Cognitive Reconstruction of Knowledge Model (CRKM) (Dole & Sinatra, 1998) views the interaction between the individual and the message characteristics as central to the change process. According to the CRKM, message characteristics refer to the instructional content. These characteristics include comprehensibility, coherence, plausibility, and whether the individual finds the message to be rhetorically compelling. When one of these characteristics is missing from the message the likelihood of change is low (Sinatra, 2005).

Characteristics of the individual include the strength, coherence, and level of commitment the learner has to their existing knowledge. Dole and Sinatra (1998) explain that change is more difficult when the prior beliefs are conceptually strong. In addition, change is unlikely when the individual is deeply committed to those beliefs. Motivational characteristics of the individual include dissatisfaction with current beliefs, personal relevance of the new message, social context, and the individual’s need for cognition.

The interaction between the learner and the message characteristics is at the heart of the CRKM because it determines the degree of cognitive engagement of the learner with the message. Linnenbrink (2007) defines cognitive engagement as the quality of the individual’s thinking in relation to cognitive strategies such as elaboration and rehearsal as well as metacognitive strategy use and self-regulated learning. Dole and Sinatra hypothesize that engagement lies on a continuum ranging from “low cognitive engagement to high metacognitive engagement” (p. 121). High elaboration is associated with central processing (Petty & Cacioppo, 1986) and involves deep, systematic processing of the message. Deeper levels of engagement increase the likelihood of
change. In contrast, low cognitive engagement typically results in superficial, heuristic processes, which decrease the likelihood of change. Change is possible through the peripheral route, though Dole and Sinatra explain that it is most likely and more enduring when processed through the central route.

An individual will process the message through either the central or the peripheral route (Dole & Sinatra, 1998; Petty & Cacioppo, 1986). It is possible that peripheral cues may induce individuals to attend more closely to the central arguments. Peripheral cues can include the length, format, and organization of the message. Hynd (2003) argues that an individual may use both routes at the same time, using all available cues to determine whether they will believe the message. Researchers have found that it is the interaction between the individual’s characteristics and the message characteristics that determines whether central or peripheral processing will occur (Dole & Sinatra, 1998; Petty & Cacioppo, 1986).

The CRKM acknowledges the role of affect as being a characteristic of motivation and personal relevance. Personal relevance in this model addresses the individual’s self-efficacy, interest, and emotional involvement (Sinatra, 2005). It can be argued that the stronger the emotional commitment the learner has to their prior beliefs, the less likely change will occur.

One limitation of the CRKM is that while it acknowledges an affective component it does not explain how affect influences the change process (Southerland & Sinatra, 2005). In contrast, Gregoire (2003) developed the Cognitive-Affective Model of Conceptual Change that describes affect as directing the change process.
Cognitive-Affective Model of Conceptual Change

The Cognitive-Affective Model of Conceptual Change (CAMCC) was developed by Grégoire (2003) in an effort to understand why practicing teachers are resistant to adopting reform-oriented mathematics curricula that conflict with their prior pedagogical beliefs. Central to the CAMCC is the view that motivation and ability influence cognitive processing as well as the mediating role of cognitive processing on attitude change. In addition, Grégoire explains that the individual’s prior beliefs and goals influence what they attend to in the environment.

Emotional responses to messages direct the level of engagement the individual has with the message. According to the CAMCC, emotional responses occur prior to processing the message and “as part of the appraisal process, serve as additional information for individuals as they interact with a complex, stressful message” (Grégoire, 2003, p. 168). Positive and neutral emotions lead to shallow, heuristic processing of the message. Grégoire explains that positive emotions may influence the learner to pay less attention to the message because they do not want to spoil the good mood they are experiencing.

In contrast, negative emotions, such as fear and anxiety, promote deeper, systematic processing of the message. Gregoire argues that stress can lead to greater conceptual change if the individual has high self-efficacy and perceives the learning context as a challenge. However, if the individual has weak efficacy beliefs, he or she is likely to perceive the message as a threat and engage in avoidance behaviors.

Gregoire (2003) cautions that systematic processing does not guarantee conceptual change will occur. However, systematic processing ensures that the individual
will process the message intentionally. In line with Posner et al. (1982), Grégoire also explains that conceptual change is most likely when the individual perceives the message as intelligible, plausible, and fruitful.

Belief Change

Beliefs about the Nature of Science

The nature of science (NOS) has been described by some researchers as the assumptions and values inherent to scientific knowledge and its development (Khishfe & Abd-El-Khalick, 2001; Lederman, 1992; Lederman & Lederman, 2004). Central elements of NOS include the tentative nature of science knowledge, the role of observation, evidence derived through experimentation, and rational arguments in constructing scientific knowledge (Duit, Niedderer, & Schecker, 2007). These aspects of NOS have been emphasized in recent science education reform documents including Benchmarks for Science Literacy (AAAS, 1993).

For the present study, two of these characteristics were emphasized: the tentative nature of science knowledge and the justification and warrants for science knowledge. Past research has demonstrated that these two aspects of NOS are accessible to upper elementary-age students (Khishfe & Abd-El-Khalick, 2001; Mason, in press). The tentative nature of science is of importance to this study because students must understand that science knowledge is subject to change as new information challenges existing knowledge (AAAS, 1993) in order to understand a key element of the decision to change the definition of planet. For example, a central argument supporting the need to change the definition of planet was the discovery of the Kuiper Belt in the 1980s (Soter,
This discovery expanded what scientists previously knew about our solar system. The Kuiper Belt is made of icy solar objects, some even larger than Pluto. As a result, many scientists called for a new definition of planet. In the present study, it may be necessary for students to understand the tentative nature of science in order for them to hold favorable attitudes towards the reclassification of Pluto as well as to experience conceptual change about what constitutes a planet.

The second aspect of NOS selected for the present study is the justification and use of warrants in constructing scientific knowledge. Benchmarks emphasizes the importance of sixth grade students gaining an understanding that scientists make decisions based on claims that are supported by empirical evidence and confirmed with rational arguments (AAAS, 1993). This aspect is of value to the current study because young students' acceptance of the change in Pluto's planetary status may be influenced by their understanding of the use of empirical evidence and arguments. A central argument presented in the refutation text is that scientists based their decision to change the definition of planet on the discovery of new objects in our solar system, including those in the Kuiper Belt.

In contrast to the NOS aspects emphasized in Benchmarks (AAAS, 1993) past research has found that young students often hold NOS beliefs that science knowledge is unchanging and true and are unable to distinguish between evidence and knowledge (Khishfe & Abd-El-Khalick, 2002). Similarly, researchers investigating epistemological beliefs in the domain of science have found that young students often believe that information contained in textbooks is true, science knowledge is static, absolute, and
transmitted by authorities (Bell & Linn, 2002; Elder, 2002; Mason, in press; Conley et al., 2004).

The aspects of research in students’ NOS beliefs and research in students’ epistemological beliefs about the domain of science are quite similar as noted above. These two constructs differ, however, in that the nature of science is related to how scientists as a community construct knowledge (Lederman, 1992) and epistemological beliefs are related to how the individual perceives the nature of knowledge and knowing (Hofer, 2000). In the present study, students’ beliefs about the nature of science are epistemic.

In the following section I describe how researchers have defined epistemological beliefs as well as some of the research that has investigated students’ epistemological beliefs related to science knowledge and knowing. Then I will describe the development of the Epistemological Beliefs Survey as a tool for measuring students’ beliefs about the nature of science (Conley et al., 2004) as this instrument was used in the present study.

Epistemological beliefs

Epistemological beliefs have been described by researchers as an individual’s beliefs about the nature of knowledge and knowing (Hofer, 2000; Hofer & Pintrich, 1997; Kuhn, Cheney, & Weinstock, 2000). Perry (1999) pioneered this line of research in the 1950s and 1960s when he collected qualitative data on college students’ experiences at Harvard University. According to Perry, epistemic beliefs follow a directional pattern of developmental progression. These categories, in sequential order, include dualistic (absolutist view), multiplistic (diverse viewpoints acknowledged), relativism (each person’s views are relative to the situation), and commitment to relativism (knowledge
and truth are evolving). Perry also found that many undergraduate students hold beliefs that knowledge is certain, simple, and transmitted from authority figures.

A separate approach to epistemic beliefs research suggests that these beliefs are independent rather than developmental. Schommer (1990) builds on Perry’s findings and proposes five dimensions of epistemological beliefs. Each independent dimension is viewed as a continuum from less constructivist beliefs to more advanced constructivist beliefs: structure (isolated facts vs. interconnected concepts), certainty (stable vs. evolving), source (externally transmitted vs. internally constructed), control of acquisition (fixed vs. incremental), and speed (fast learning vs. gradual learning). Hofer and Pintrich (1997) argue that the dimensions of control and speed are not epistemological in nature. Rather, control of acquisition concerns the nature of intelligence and speed concerns the nature of learning.

Hofer (2000) proposes four independent dimensions of epistemological beliefs including certainty (knowledge as fixed or fluid), simplicity of knowledge (accumulation of facts or highly interrelated concepts), source (externally transmitted or internally constructed) and justification (use of evidence). The first three of these dimensions are similar to those suggested by Schommer (1990). However, justification is often used by researchers who hold a developmental view on epistemological beliefs (Hofer, 2000; King & Kitchner, 1994; Kuhn 2005). Researchers have provided some evidence in support of these dimensions (see Hofer & Pintrich, 1997).

Measuring epistemological beliefs. Elder (2002) examined fifth-grade students’ beliefs about the nature of science along four dimensions: source (externally transmitted or internally constructed), certainty (belief in a right answer), development (science
knowledge as evolving), and justification (use of evidence). These dimensions are similar to those examined by Schommer (1990) and Hofer (2000). Students’ completed a 25-item Likert-scale survey as well as a written questionnaire regarding their NOS beliefs.

In creating the epistemological belief scales, Elder (2002) grouped the 25 items into four scales according to theoretical criteria (source, certainty, development, and justification). Multidimensional scaling (MDS) was used to confirm the scales. Elder explains, “MDS is a technique for exploring and understanding the underlying structure of data that uses similarity information among items to create a descriptive model for representing the data” (p. 358). As a result, three scales were created: Change, Reason, and Authority.

Epistemological beliefs survey. Conley and colleagues (2004) used the Epistemological Belief Scale (Elder, 2002) as the framework for developing the Epistemological Beliefs Survey. Conley et al. examined four dimensions of fifth grade students’ beliefs about the nature of science: source, certainty, development, and justification. The survey was administered to participants at the beginning and the end of a nine week science unit. The purpose of Conley et al. study was to examine how students’ beliefs about science change over time.

The self-report epistemological belief scale consists of 26 items rated on a 5-point Likert scale (1 = strongly disagree; 5 = strongly agree) (Conley et al., 2004). All of the items focus on the domain of science. Conley and colleagues report that by using confirmatory factor analysis (CFA) they were able to replicate Elder’s (2002) finding that the four epistemological belief dimensions (Source, Certainty, Development, and Justification) are measured with the Epistemological Beliefs Survey.
For the present study, I used an adapted version of Conley et al. (2004) Epistemological Beliefs Survey. This shortened version was developed by Mason (in press) to examine fifth grade students’ beliefs about the nature of science. Mason abbreviated the survey to focus on two dimensions: Certainty and Development. These two dimensions of students’ NOS beliefs are the most relevant for the current study. Mason reports the overall alpha reliability coefficient of the adapted version of the instrument is .73.

Attitude Change through Persuasion

*Elaboration Likelihood Model*

A seminal model of persuasion used across educational psychology and social psychology is the Elaboration Likelihood Model (ELM) (Petty & Cacioppo, 1986). The ELM proposes two routes to change: the central route and the peripheral route. The central route is linked to deep cognitive processing of the message as the individual weighs its merits. In contrast, the peripheral route is associated with superficial processing where the individual is less likely to scrutinize the merits of the message.

Central to the ELM is elaboration, “the extent to which a person thinks about the issue-relevant arguments contained in a message” (Petty & Cacioppo, 1986, p. 128). Elaboration involves deep cognitive processing in which the individual is attending to the message and evaluating its merits, resulting in a general evaluation, or attitude toward, the persuasive message. Issue-relevant elaboration is likely to result in the assimilation or accommodation of the new message into the individual’s existing schema for the attitude object.
Factors that influence elaboration which is the individual's ability to critically evaluate a message include personal relevance, need for cognition, prior knowledge, message comprehensibility, and the individual's initial attitudes toward the message (Petty & Cacioppo, 1986).

**Persuasion**

Persuasion is the process of initiating a shift in an individual's beliefs or understanding of a particular topic by fostering deep engagement through argument and reasoning (Alexander, Buehl, & Sperl, 2001; Hynd, 2003). Persuasion often occurs through the interaction between the individual and a text (Petty & Cacioppo, 1986). Some conceptual change researchers suggest that when change results from reading a persuasive text it is most likely due to the readers' deep cognitive engagement with the ideas presented in the text (Buehl et al., 2001; Dole & Sinatra, 1998).

**Resistance to persuasion.** Resistance has been described by social psychologists as the act of withstanding influence (Knowles & Linn, 2004). Individuals may resist change when their prior knowledge is deeply entrenched as may be the case with students' knowledge of Pluto's planetary status (Dole & Sinatra, 1998; Vosniadou & Brewer, 1992). They may also resist change if they are not dissatisfied with their existing conception when presented with the new information in the text, or if they do not find the new information plausible, intelligible, or fruitful (Posner et al., 1982). Further, resistance to persuasion may also occur when the topic is highly personally relevant to the individual (Petty & Cacioppo, 1986).

Topic-relevant prior knowledge can also foster resistance to persuasion or change. This seeming paradox poses a challenge for fostering change. For example, researchers
have demonstrated quite convincingly that prior knowledge facilitates understanding of new concepts (Anderson & Pearson, 1984; Anderson, Reynolds, Schallert, & Geotz, 1977). In contrast, high levels of relevant prior knowledge may result in lower levels of engagement with the message in the text and thus increase resistance to change (Buehl et al., 2001; Petty & Cacioppo, 1986; Pintrich et al., 1993). Further, a lack of adequate prior knowledge related to the new information in the text can result in a lack of understanding of that information which may also result in resistance to change (Duit, 2002).

It may also be the case that when an individual is confronted with a message that explicitly and directly refutes their prior beliefs that they may reject the message altogether. This has important implications for the use of refutation text in the present study. Chinn and Brewer (1993) postulate seven ways that individuals deal with anomalous data. These responses include: ignoring or rejecting the new information, excluding the information from the prior belief, holding the new information in abeyance, reinterpreting the information while retaining the prior belief, reinterpreting the information and making a peripheral change to the prior belief, and accepting the information. Negative emotional responses to anomalous data could result in the individual rejecting or ignoring the information rather than engaging in careful processing of the message (Gregoire, 2003).

One of the paradoxes of resistance to change lies in the level of engagement with the message. On one hand, deep engagement with a message increases the likelihood of change (Dole & Sinatra, 1998; Gregoire, 2003; Petty & Cacioppo, 1986). However, deep engagement may also be the result of the individual forming a counterargument to the
message (Wegener, Petty, Smoak, & Fabrigar, 2004). In such instances, individuals are likely to resist persuasion and maintain their original attitudes.

Moreover, when an individual is confronted with a message that contradicts their original attitude, the individual may become even more deeply committed to their original position (Alexander et al., 2001; Petty & Cacioppo, 1986). The individual may also tend to evaluate information that supports their initial attitudes in more positive ways than information that counters those attitudes, even if that information is founded on stronger warrants than the individual’s attitude (Kardash & Scholes, 1996). This may especially be the case with controversial issues.

A similar form of resistance is casebuilding (Buehl et al., 2001). Casebuilding is a form of resistance to persuasive messages presented in refutation texts whereby the individual selectively attends to only those arguments which support their prior conceptions. Casebuilding involves high levels of engagement with the text although it serves to strengthen the individual’s prior knowledge. Resistance to change occurs when casebuilding reinforces misconceptions.

Individuals may also experience emotions such as distrust (“I don’t believe it”) and resistance (“I don’t like it”) when they read refutation texts (Knowles & Linn, 2004). This effect may be of particular relevance when reading about controversial topics. Emotional responses may lead the individual to reject or ignore the instructional content of the text. Personal relevance may also increase resistance to change (Dole & Sinatra, 1998; Duit, 1999). In contrast, individuals may not devote cognitive resources to a topic in which they have little interest (Buehl, et al., 2001; Gregoire, 2003).
Reducing resistance to change. Fuegen and Brehm (2004) argue that an effective way to reduce affectively-based resistance to a message is to provide a weaker message that does not directly threaten the individual's beliefs or values. This assertion conflicts with the literature in conceptual change that shows strong, repeated messages that induce cognitive conflict are the most effective in promoting change (Posner et al., 1982; Guzzetti et al., 1993; Hynd, 2003). However, if the topic of change is controversial and associated with high emotional responses, the likelihood of change may be increased through using weaker arguments that may reduce the emotionally-based resistance to the message. Future research is needed to investigate whether this is the case with controversial conceptual change.

Over the past several decades researchers in educational psychology and social psychology have been investigating the influences of affect on cognitive processing (Bless, 2000; Lazarus, 1982; 1984; Rosenberg, 1998; Zajonc 1980). In educational psychology, research on affect and emotions has centered primarily on test anxiety with very little research focusing on the relationship between emotions and cognitive processing in classroom settings (Pekrun et al., 2002; Linnenbrink & Pintrich, 2002; 2004). In the following section I describe some of the seminal research from social psychology on the link between affect and cognitive processes as they relate to the present research. First, I make the distinctions between affect, mood, and emotions. Then, I briefly describe current social psychological theories that link affect to cognitive processes, and how those processes can be applied to conceptual change learning.
Emotions and Cognitive Processing

Researchers have shown that affect and cognition are distinct but interdependent constructs (Lazarus, 1982; Zajonc, 1980). Lazarus (1984) asserts that emotions are powerful influences on how we think and interpret events. Emotional responses are quick, automatic, and can occur unconsciously (Rosenberg, 1998). In what follows, I provide a description of the research on the influence of emotions and cognitive processes from both social psychology and educational psychology.

Definitions of Affect, Moods, and Emotions

Researchers have not arrived at a universal definition of affect (Linnenbrink, 2006; Linnenbrink & Pintrich, 2004). However, it is necessary to provide a working definition of affect for understanding the relationship between affect and cognition in this research. I rely on Rosenberg’s (1998) hierarchy of affect, mood, and emotions because it is commonly used as the operational definition among social psychologists and educational psychologists.

Affect. Definitions of the construct of affect are often inconsistent, in that affect, mood, and emotions are often referred to interchangeably in the literature (Linnenbrink, 2006). One definition of affect is the “simple pleasant or unpleasant tone of a feeling,” (Leary, 2000; p. 332). In an attempt to clearly define affect, Rosenberg (1998) describes the differences between affective traits and affective states. Rosenberg postulates a hierarchy of affect which consists of three levels: affect, moods, and emotions. Affective traits reflect a predisposition towards emotional responses that tend to remain stable throughout one’s lifetime. According to Rosenberg, affective traits are embedded within personality traits and influence affective states. This influence occurs without conscious
awareness of the individual. The two classes of affective states are moods and emotions. These affective states are less stable and enduring than affective traits. A more detailed description of the affective states of moods and emotions follows.

**Moods.** Moods are considered to be at an intermediate level between affective traits and emotions. The source of moods is not clear (Linnenbrink & Pintrich, 2004). According to Rosenberg (1998), moods are temporary, fluctuating across situations, but they can last for days. Moods are not as enduring as affective traits or as short-lived as emotions. Moods exert a background influence on cognition, but the individual is more likely to be aware of this influence than of the influence of affective traits. Moods are at the middle level of the hierarchy because they have an organizational influence on emotions.

**Emotions.** Emotions are the most fleeting and temporary state of the affective hierarchy. Emotions typically occur in response to a specific person or event (Linnenbrink & Pintrich, 2004). Rosenberg (1998) describes emotions as “brief, psychophysiological changes that result from a response to a meaningful situation in one’s environment” (p. 250). Emotional responses are quick, automatic, and can occur unconsciously. Emotions can fade into mood states over time (Linnenbrink & Pintrich, 2004). Emotions can also occupy the foreground of one’s thoughts, overwhelming consciousness. Rosenberg asserts “emotions demand our attention, forcing us to set priorities and to deal efficiently with life-relevant situations” (p. 250).

Hence, according to Rosenberg (1998), affective states are those enduring personality traits that influence emotional responses. Moods are longer lasting than emotions but not as long lasting as affective states. Moods can influence emotional
responses. Emotional reactions occur primarily in response to an event or individual and are fleeting and intense. It is this level of affect that is of interest in the present study, especially the link between emotions and cognitive processing in response to a message about a controversial topic.

Rosenberg’s (1998) theory of affective states addresses the link between affect and cognitive processing at a general level. In the next section I discuss theories from social psychology that describe how affect influences the ways in which information is processed and stored in memory.

Theoretical Approaches of Affect and Cognitive Processing

Mood congruent processing and recall. In an attempt to explain the differences in information processing and memory retrieval in relation to mood, Forgas (2000) developed the Affect Infusion Model (AIM). According to this model, affect influences both what people think (information) and how people think (processes). Both positive and negative moods influence the encoding and retrieval of information from memory only when there is constructive, deep cognitive processing of the information. Negative moods are more likely to trigger bottom-up, careful processing of the information. In contrast, positive moods are associated with top-down, shallow, heuristic processing and have little opportunity for generating mood-congruent knowledge structures. According to Forgas, mood congruency refers to the influence of mood on the information people process and how they process it. For example, if a person is in a positive mood when they see an entertainer such as Jerry Seinfeld they may laugh enthusiastically at his jokes. In contrast, if that same person is in a negative mood when they see Jerry Seinfeld they may find his jokes to be annoying.
Forgas (2000) asserts that mood congruent effects are associated with heuristic and substantive, or elaborated processing. Heuristic and substantive processes are viewed as constructive and open, allowing mood to influence cognition. Heuristic processing is most common when the task is simple, familiar, or of little personal relevance. Mood congruent effects are facilitated through heuristic processing when the individual mistakenly attributes their mood as informing their evaluative responses.

Substantive processing, or deep cognitive processing, occurs when the individual is faced with learning new information or linking their background knowledge with new information. The constructive nature of substantive processing allows for mood to infuse the thought process (Forgas, 2000). Mood also activates information from long-term memory, fostering access to mood congruent schema used in making meaning of the situation.

*Dual process model.* Fiedler’s (2000) dual process model is based on Piaget’s notions of assimilation and accommodation. The central assumption of this model is that negative moods are associated with accommodation which facilitates deeper processing of specific message details. Negative moods may signal that adapting current knowledge structures is not progressing correctly and that the individual may need to attend more closely to the information in order to adapt appropriately. Negative moods lead to careful, detail-oriented processing.

In contrast, positive moods are associated with assimilation and the reliance on general knowledge structures to process information. Positive moods signal that learning is proceeding well and that prior knowledge is appropriate for the task.
Mood-and-general knowledge theory. The mood-and-general-knowledge theory (Bless, 2000) describes the basic relationship between moods and cognitive processing. Positive moods are associated with top-down, heuristic processing and negative moods are linked with bottom-up, systematic processing. However, Bless does not take the view that people in positive moods are unmotivated, resulting in heuristic processing. Instead, positive moods signal that it is acceptable to rely on general knowledge structures. As a result, people in positive moods may ignore or not detect information that is inconsistent with their prior knowledge.

Researchers have investigated the differences in cognitive processing that may be associated with positive moods and negative moods. For example, Bless, Bohner, Schwarz, and Strack (1990) examined the effects of good and bad moods on either weak or strong persuasive arguments under conditions that do or do not foster elaboration of the argument. The findings of this study suggest that negative moods may increase cognitive engagement and elaboration of a message. Additionally, elaboration may decrease as the result of positive moods. However, elaboration of a message may occur when the individual is in a good mood if they receive explicit instruction to focus on the ideas in the message (Bless et al., 1990).

Further exploration of the influence of moods on the reliance of general knowledge scripts was conducted by Bless and colleagues (1996). This series of studies examined whether positive moods increase and negative moods decrease reliance on scripts, a form of general knowledge structures. Bless et al. explain that scripts consist of a typical sequence of events that represent typical activities. An individual may rely on a
relevant script for interpreting information. Information that is already part of an
individual's script can be processed efficiently and recalled easily.

Findings revealed that participants in a positive mood were more likely than
participants in a negative mood to report a typical item as having been included in the
story (Bless et al., 1996). This occurred even when a particular typical item was not in the
recorded story. Individuals in negative moods were more likely to report atypical items
that had been presented in the recordings than individuals in positive or neutral moods.
Further, recognition of atypical items was not affected by type of mood. These findings
suggest that positive moods increase reliance on general knowledge structures while
negative moods decrease such reliance.

Bless et al. (1996) suggest that by relying on scripts, individuals in positive
moods can free up cognitive resources that can be applied to a secondary task. This
finding has implications for the present study. If it is the case that the reliance on scripts
by individuals in a happy mood is not the result of a reduction in cognitive processing,
then it is possible that positive emotions can be associated with high levels of
engagement. This increased engagement with the new information may also increase the
likelihood of change (Dole & Sinatra, 1998).

As demonstrated in the studies previously described, positive moods may result in
less complex processing of the information at hand (Bless et al., 1990; Bless et al., 1996).
However, Bless (2000) asserts that when the individual detects an inconsistency between
their prior knowledge and the new information, the inconsistent information will receive
more processing attention. Thus, it is not that cognitive processing is decreased as a result
of mood. Rather, it is the allocation of processing resources that differ. Happy moods are
likely to lead to reliance on scripts which require less attention so that cognitive resources can be allocated to information that is inconsistent with the script. These findings have implications for the use of refutation text as an intervention because they suggest a mechanism by which refutation text has its effect.

One limitation of the theories just described is that they address moods and cognition at a general level. Pekrun and colleagues (2002) provide insights on emotions and cognition at the classroom level, and thus provide a useful perspective for the proposed research. In addition, Pekrun et al. distinguish the ways in which positive emotions can facilitate or impede learning and the ways negative emotions can facilitate or impede learning.

*Emotions and Cognition in Academic Settings*

Pekrun and colleagues (2002) define emotions that relate specifically to academic learning and classroom instruction as *academic emotions*. This category of emotions focuses on students' emotions in relation to studying, test taking, and attending class. Pekrun et al. describe a two-dimensional model of emotions that includes valence (positive/negative) and activation (activating/deactivating). Activation refers to mobilization, arousal, and energy (Linnenbrink, 2007). Positive activating emotions include enjoyment, pride, and hope, while relief would be considered a positive deactivating emotion. Negative activating emotions include anxiety, anger, and shame, with negative deactivating emotions corresponding to boredom and hopelessness.

According to Pekrun et al. (2002), both positive and negative activating emotions can facilitate academic achievement. For example, positive activating emotions may increase motivation, critical thinking, elaboration, and metacognitive strategy use.
Negative activating emotions can decrease motivation, foster off-task thinking and rehearsal strategies. However, Pekrun and colleagues argue that negative activating emotions can strengthen extrinsic motivation when overall learning expectancies are positive. Emotions such as anxiety and shame can often be beneficial to academic achievement because they may increase the student's motivation to carefully process the information in order to succeed with the learning task.

In contrast, deactivating emotions are commonly associated with lower levels of academic achievement than activating emotions. Pekrun and colleagues (2002) explain that negative deactivating emotions diminish motivation, directing attention away from the task, resulting in superficial cognitive processing. Positive deactivating emotions may temporarily reduce cognitive processing, but the influence of positive responses may increase long-term motivation to continue putting forth cognitive effort to the task. How these emotions relate to the conceptual change process is examined in a later section.

Measuring academic emotions. The Achievement Emotions Questionnaire (AEQ) is a self-report instrument intended to measure a number of discrete emotions within three main categories of academic contexts: attending class, studying, and taking tests and exams (Pekrun, Goetz, & Perry, 2005). Pekrun et al. (2002) postulate that these three academic settings are characterized by different social structures and functions which may result in different emotional experiences in each setting.

The AEQ was developed in a series of quantitative and qualitative studies that investigated college students’ achievement emotions (Pekrun et al., 2002). The five exploratory qualitative studies investigated the emotions of high school and undergraduate students through interviews and questionnaires. Participants provided
information about the elements and quality of emotions, as well as the origins and consequences of those emotions, experienced in academic contexts. The findings of the five studies revealed that students' experience a range of positive and negative emotions in academic settings.

Pekrun et al. (2002) explain that virtually every human emotion was reported with the exception of disgust. The emotion mentioned most frequently was anxiety and it was prevalent across the three academic contexts. Positive emotions of enjoyment of learning, pride, hope, relief as well as negative emotions such as anger, shame, and boredom were reported most often. Further, positive and negative emotions were reported at almost equal frequencies.

In developing the scales for the AEQ, Pekrun and colleagues (2002) endeavored to use the emotions that play a role in academic contexts. Consequently, the eight emotions identified in the five exploratory qualitative studies were used. These emotions are: enjoyment, hope, pride, anger, anxiety, hopelessness, shame, and boredom. Pekrun et al. wanted to make sure the categories included valence (positive/negative) as well as activation (activating/deactivating), suggesting that these two dimensions of emotions can be regarded as “basic determinants of many effects of emotions” (p. 95).

The data provided in the qualitative studies were used in item construction for the AEQ along with theoretical considerations and information from other instruments previously used to measure test anxiety (Pekrun et al., 2002). Preliminary item scales were selected by using criteria of redundancy and expert judgment. The items selected for the final versions were based on confirmatory factor analysis for each scale as well as the item statistics of the preliminary versions.
Confirmatory factor analysis revealed that internal structures of academic emotions can differ between emotions (Pekrun et al., 2002). Those items relating to the cognitive, physiological, motivational, and affective components separated in some scales (e.g., test anxiety scale) but showed less differentiation in others (e.g., hopelessness and boredom scales). A moderate correlation was found for learning-related and class-related emotions with their counterparts relating to tests (average $r = .58$). Correlations were somewhat higher for learning-related versus class-related emotions (average $r = .64$).

Analysis of the interrelations of different emotions within these three groups revealed four clusters of emotions: (a) hope, pride, and enjoyment; (b) relief; (c) anxiety, hopelessness, and shame; (d) anger and boredom. Pekrun and colleagues (2002) explain that the “clusters suggest that emotions can be grouped according to their antecedents” (p. 96). For example, hope, pride, and enjoyment may be induced by positive events. In contrast, relief may be induced when a negative event is stopped. Anxiety, hopelessness, and shame may result from a lack of subjective control, whereas anger and boredom may be linked with higher levels of control.

Shorter, eight-item versions of the AEQ were also developed. The scales were administered with alternative instructions for use in single classrooms and to transient emotional states. Pekrun et al. (2002) report the average reliabilities for these versions as .87 (short trait versions), .86 (course-related versions) and .87 (state versions).

The three scales of the AEQ have been designed to be modular and can be used together or separately (Pekrun et al., 2005). Recall that these scales include learning-related, classroom-related, and test-related emotions. Further, within each section the different emotion scales can be used separately (e.g., using only the enjoyment scale.
within the learning-related emotions scale). The AEQ manual (Pekrun et al., 2005) provides a detailed breakdown of the means, standard deviations, and reliability coefficients is provided for each item as well as for each scale.

Emotions and Conceptual Change

Educational psychologists have postulated that the process of conceptual change includes an affective component (Dole & Sinatra, 1998; Gregoire, 2003; Pintrich et al., 1993; Sinatra, 2005). Negative moods may increase the likelihood of deep cognitive processing of information (Bless, 2000; Forgas, 2000; Pekrun et al., 2002). Negative moods may also serve as cues, signaling inconsistencies between the individual’s prior knowledge and the information at hand (Limon, 2003). In addition, negative moods are associated with accommodation (Fiedler, 2000), which educational psychologists argue is the process through which conceptual change occurs (Dole & Sinatra, 1998; Gregoire, 2003; Posner et al., 1982). However, negative emotions such as fear and anxiety may also lead to the individual perceiving the anomalous information as a threat and thus resist change (Linnenbrink & Pintrich, 2002).

Positive moods may influence conceptual change, belief change, and attitude change if the individual is able to recognize the inconsistency between their prior knowledge and the information presented to them. Bless (2000) argues that positive moods use less complex processing strategies until a discrepancy is noticed. Once the discrepancy is noticed, the individual will engage in deeper level processing of the conflicting information. It is possible that an individual who experiences positive emotional responses to anomalous information may be willing to give thoughtful consideration of that information even when it conflicts with their prior knowledge.
(Linnenbrink, 2002). Pekrun et al.'s (2002) model supports this view, explaining that positive activating emotions can induce critical thinking, elaboration, and metacognition. As a result, the likelihood of conceptual change increases.

One instructional intervention that has been shown to be effective in promoting deep cognitive processes, which in turn increases the likelihood of change is refutation texts. The following section describes how refutation texts have been used to promote conceptual change.

Refutation Texts

Refutation texts will be used in the present study because researchers have demonstrated that texts designed to refute misconceptions help to facilitate conceptual change (Guzzetti et al., 1993; Hynd, 2001; Limon, 2003; Mason & Boscolo, 2004). A refutation text is one that specifically elicits a common misconception about a topic, directly refutes it, and introduces the scientific explanation as a viable alternative (Hynd, 2003; Mason, in press). A goal of learning from reading science texts is the learner's ability to construct a new mental model that aligns with the scientific explanation presented in the text (Mikkila-Erdmann, 2002). Kintsch (1988) developed the construction integration model to explain how mental models are formed as a result of the integration of the reader's prior knowledge and the information in the text.

Constructing Mental Models through Reading

Construction Integration Model. Refutation texts may help students construct new mental models of a scientific phenomenon based on the information in the text. Kintsch's (1988) Construction Integration Model hypothesizes that the reader's prior knowledge is
integrated with information in the text. The reader may reorganize the information from the text, restructuring it based on their prior knowledge rather than the information presented in the text, resulting in an incremental mental model change (deLeeuw & Chi, 2003; Mikkila-Erdmann, 2002).

According to Kintsch (1988), reading comprehension occurs in two phases. In the construction phase a network of associations of the reader’s propositions and concepts are automatically constructed. In the integration phase associations that do not fit with the text’s meaning are discarded. In relation to conceptual change, as learners read refutation text they integrate their prior knowledge with the new information in the text. This often results in the formation of a new mental model of the phenomenon under study (deLeeuw & Chi, 2003; Mikkilia-Erdmann, 2002).

Students often assimilate elements of the scientific explanation into their existing mental models, distorting the scientific concepts, while at the same time adding or deleting beliefs from their existing mental model, resulting in a synthetic model (Hynd, Alvermann, & Qian, 1997; Vosniadou, 2002). Gradually, with repeated exposure to the scientific information, the synthetic model can be revised to align with the scientific explanation.

Refutation Text Format

In contrast to traditional expository texts, refutation texts provide the reader with a clear, concrete explanation of the concept under study. Refutation texts are designed to state common misconceptions about a phenomenon, refute those ideas, and then present the scientific explanations as plausible and fruitful alternatives (Guzzetti et al., 1993; Hynd, 2001; Murphy, 2001). The refutation sentence may serve to make explicit the
difference between the readers' prior beliefs and the scientific explanation which increases the likelihood of change (Vosniadou, 2001).

Refutation texts are written so that learners will find them clear and detailed (intelligible) (Mikkilia-Erdmann, 2002; Murphy, 2001). Examples provided within the refutation texts are believable (plausible) and they typically explain the usefulness of the scientific theory (fruitfulness) (Hynd, 2003). These characteristics align with the CRKM (Dole & Sinatra, 1998) that an individual is more likely to engage in deep cognitive processing of a message that is comprehensible, coherent, plausible, and rhetorically compelling.

Further, the refutation sentence may increase the reader's engagement with the text (Murphy, 2001). Recall that negative emotions are associated with detail-oriented, careful processing of the message (Bless, 2000; Fiedler, 2000; Forgas, 2000; Pekrun et al., 2002). Deeper engagement may result from the individual finding the refutation segment personally relevant because the misconception presented in the text is similar to that which the individual holds. The refutation sentence directly rejects the misconception which may lead the individual to consider the ensuing scientific explanation more thoughtfully and critically. This deeper engagement often increases the likelihood of conceptual change (Dole & Sinatra, 1998) and may be more critical when students are reading about controversial topics.

The effectiveness of refutational text was demonstrated in research conducted by Guzzetti and colleagues (1993). Guzzetti et al. conducted a meta-analysis of the research in reading and science education to examine the instructional interventions developed to promote conceptual change in science learning. The average effect size identified by
Guzzetti and colleagues was $\Delta = .28$ ($n = 11$). An important finding across both the reading education and science education research is that the most effective intervention strategies for promoting conceptual change are those which foster cognitive conflict. For example, refutation texts are used to assist students with identifying inconsistencies in their conceptual knowledge, thus creating cognitive dissonance. This cognitive dissonance can lead to systematic, detail-oriented cognitive processing which increases the likelihood of change (Dole & Sinatra, 1998; Petty & Cacioppo, 1986). It is important to note that cognitive dissonance is useful but not necessary to facilitate conceptual change (Chi & Roscoe, 2002).

Some possible limitations of refutation texts as a conceptual change intervention include both individual factors and text factors. For example, the individual must have the ability to notice the discrepancy between their current ideas and the new information presented in the text if change is likely to occur (Chi & Roscoe, 2002; Chinn & Brewer, 1993). Refutation texts may not promote critical thinking because they seem to tell the reader what to believe and why (Hynd, 2001). However, empirical evidence suggests that refutation texts can induce critical thinking as the result of the cognitive dissonance that can arise between the individual’s current ideas and the new information (Guzzetti et al., 1993; Hynd, et al., 1997; Mason, in press).

Conceptual Change and Refutation Texts

Recently, research in conceptual change has emphasized interventions such as hands-on inquiry activities (see for example, Hallden, Petersson, Scheja, Ehrlen, Haglund, Osterline, & Stenlund, 2002; Ivarsson, Scholtz, & Saljo, 2002; Vosniadou,
loannides, Dimitrakopoulou, & Papademetriou, 2001) and computer simulations (Biemans & Simons, 2002; Nussbaum & Sinatra, 2003; Wiser & Amin, 2002). As a result, it was challenging to find studies conducted recently that use refutation texts as an intervention.

The following studies were purposefully selected for their relevance to the current study based on their use of refutation texts in promoting conceptual change with science topics.

*Refutation Texts and Instruction*

The interrelationship between refutational texts and classroom instruction to promote conceptual change was examined by Diakidoy, Kendeou, and Ioannides (2003). The refutation text is of interest because it confronts two concepts instead of a single concept as typically presented in refutational texts. The topics addressed were energy sources, and transformation and storage of energy. The passage consisted of four sections, including two paragraphs that explicitly confronted the reader's alternative conceptions.

Participants for Diakidoy et al. (2003) were sixth grade students. Two experimental groups and one control group were used. Experimental group 1 read an expository text written to reinforce the two concepts covered during instruction. Experimental group 2 read a refutational text adapted from the expository text in addition to receiving direct instruction. The control group received only direct instruction.

Findings revealed that students who read the refutational text in connection with direct instruction experienced greater levels of conceptual change than students who read
the expository text along with direct instruction, as well as the students who received only direct instruction (Diakidoy et al., 2003).

It is also interesting to note that students involved with this study did not typically read expository texts, either refutational or non-refutational, for science learning. Science lessons within this school district consisted solely of teacher lectures and workbook tasks. This study demonstrates that students can benefit from refutational texts even when they have very little background knowledge on the comprehension processes needed to interpret such texts.

Hynd, McWhorter, Phares, and Suttles (1994) investigated three variables related to conceptual change learning in science classrooms. They examined whether reading a refutation text, participating in small group discussions, and/or seeing a demonstration would promote conceptual change on students’ notions about projectile motion. Ninth and tenth grade students were randomly assigned to one of eight groups representing the two levels of text, two levels of discussion, and two levels of demonstration. Pré-, post-, and delayed posttests were used to identify students’ conceptions about projectile motion.

The refutation text developed by Hynd et al. (1994) included the nonscientific notion of impetus theory and then refuted that with information related to Newton’s explanation of motion. Students in the non-refutation group read an expository text on a non-related concept, models of the atom. Students who observed the demonstration went to a demonstration room, while the other students completed physics word games as a placebo control. Afterwards, students who were not in the discussion group returned to their classroom.
Analysis of the data revealed that the refutation text was more powerful in promoting enduring conceptual change than either demonstration or discussion alone (Hynd et al., 1994). In fact, the discussion did not help or hinder change. Students who worked individually and saw the demonstration outperformed students who worked in small groups. The demonstration had no significant effect on text type. Additionally, students in the non-demonstration group did better if they read the refutation text than those who read the expository text. This seminal study by Hynd et al. (1994) illustrates that refutation texts can be more effective than demonstrations and small group discussions in fostering conceptual change.

A limitation of Hynd et al.’s (1994) study is that the demonstration activity was simply that – a demonstration. The outcome may be different if the demonstration activity was inquiry-centered. A wealth of research has demonstrated that inquiry activities can facilitate deep cognitive engagement (see for example Kuhn, 2005), which in turn, can increase the likelihood of conceptual change (Dole & Sinatra, 1998).

Activating and Refuting Misconceptions

A seminal study by Alvermann and Hynd (2001) investigated whether activating prior knowledge and then directly and explicitly confronting misconceptions through refutation text would promote conceptual change. Alvermann and Hynd wanted to determine if providing students with written directions warning of a conflict between their prior beliefs and Newton’s theory of motion would promote conceptual change. In addition, the researchers wanted to investigate whether refutation text would facilitate reading comprehension of skilled readers who are non-science majors.
Participants were undergraduate non-science majors. A pretest was administered to all participants to assess their prior knowledge about projectile motion. Then, participants were placed in one of three conditions. Participants in Group 1 received an activation activity by being asked to diagram the path a marble would take if it were shot from a tabletop and then write a brief explanation of their reasons. Group 2 participants completed the same activation activity followed by reading a short refutation passage on projectile motion. Group 3, the control group, completed a time-in-space relativity problem that was not related to projectile motion.

Participants in the refutation group outperformed participants in the activation only group and the control group on the posttest measures of conceptual understanding (Alvermann & Hynd, 2001). The results suggest that merely activating background knowledge is insufficient for promoting conceptual change. The misconception must also be directly and explicitly refuted. A second interesting finding of this investigation is that no statistically significant differences were found for text type among competent readers. Skilled readers benefited from reading either text type. However, the refutation text was effective in promoting conceptual change among less-skilled readers, a finding of important for the design of the present study.

Alvermann and Hynd (2001) demonstrate the importance of not only activating learners' misconceptions, but also directly and explicitly refuting them in an effort to promote conceptual change. Presenting information that contradicts one's prior knowledge may induce cognitive conflict, increase engagement and the likelihood of conceptual change. In addition, this study demonstrates refutation texts can increase the
likelihood of conceptual change among students with low domain-specific knowledge and low-reading skills.

Beliefs and Refutation Texts

Conceptual change researchers have also used refutation texts in studies of epistemological beliefs as predictors of change (Mason, in press; 2001; Mason & Gava, in press). In addition, persuasive texts have been used to investigate whether individuals’ topic-relevant beliefs influence text encoding and recall processes (Kardash & Scholes, 1995). The following section presents the research on beliefs, change, and refutation texts.

Epistemological Beliefs and Conceptual Change

Mason and Gava (in press) explore the effects of students’ epistemological beliefs and conceptual change. Eighth grade students were given either a refutation text or a traditional expository text on natural selection and biological evolution. In addition to assessing the level of conceptual change as a result of reading the text passage, students’ epistemological beliefs about the nature and certainty of knowledge as well as their knowledge about biological evolution were assessed.

Students in the refutation text group had higher scores on the immediate and delayed posttests on natural selection and biological evolution. In addition, students with constructivist beliefs (e.g., knowledge is changing, uncertain) experienced higher levels of conceptual change than those who viewed knowledge as simple and certain. The authors offer one possible explanation for this phenomena by stating that students with “sophisticated epistemological beliefs are more able to take advantage of reading a text
that explicitly states and refutes their preconceptions” (Mason & Gava, in press, p. 19).

This study has implication for the use of the NOS measure in the present study, as beliefs about the nature of science are epistemic.

Mason and Gava (in press) also examined the role of metaconceptual awareness as an impetus for conceptual change. For example, findings from this study show that refutational texts promote understanding at the situational level of the learner (Kintsch, 1988). This effect may be the result of deeper cognitive processing of the text prompted by a comparison between existing knowledge and the new information. It may also be the result of the refinement of metacognitive awareness of one’s prior knowledge and the new information.

Mason and Gava (in press) provide further support for the effectiveness of using refutation text to facilitate conceptual change. What is interesting about this study is that students’ epistemological beliefs were correlated with text type. The findings revealed that students who viewed knowledge as changing and uncertain experienced greater levels of change after reading the refutation text than students’ who viewed knowledge as static and certain.

Beliefs, Epistemological Beliefs, and Controversial Issues

Mason (2001) investigated eighth-grade students’ epistemological beliefs in response to anomalous information related to controversial topics and theory change. Two topics were selected for this study, the cause of the extinction of dinosaurs and the construction of the Giza pyramids. Two text passages were written for each topic with the first text describing a common theory and the second text presenting a different, more
controversial theory. Hence, participants read a total of four text passages, two relating to theories of dinosaur extinction and two relating to the construction of the great pyramids.

Student’s topic-relevant background knowledge was assessed prior to reading the texts. Participants read the first text on the meteor impact theory for dinosaur extinction, rated it on believability, then provided a written response justifying their beliefs about this theory. Participants were then asked to read the second text passage containing information about the contradictory, more controversial theory related to dinosaur extinction. After reading the second text, participants rated it for believability and wrote a brief response justifying their beliefs about this theory. This same process was conducted on the second topic, the Giza pyramids.

A qualitative analysis of students responses revealed that participants justified their initial theory preference by referring to the source of knowledge that what scientists say and the information written in text books are true (Mason, 2001). Participants explained that they thought the evidence supporting their initial beliefs was credible, sufficient, and cohesive.

Student’s responses to the anomalous data were similar to Chinn and Brewer (1993) classification of responses to conflicting information. It is interesting to note students’ beliefs about why they rejected the contradicting theory regarding dinosaur extinction. Some students explained that scientists can be wrong. This dual belief about the role of scientists can be held by the same individual and could be used to accept or discount theories or information (Mason, 2001).

Mason (2001) is useful in providing insights as to how children respond to information that conflicts with their prior beliefs regarding controversial issues. The
findings suggest that student's beliefs about science and scientists may influence students' justifications for holding to a particular belief or preference for a particular theory.

Facilitating Students' Engagement with Refutation Texts

The research reviewed in the previous section demonstrates the effectiveness of refutation texts as an intervention for promoting conceptual change across grade levels. Researchers have demonstrated that comprehension increases with multiple readings of a text (Allington, 2001; Amlund, Kardash, & Kulhavy, 1986; Morrow & Gambrell, 2000). Moreover, researchers have shown that distributed repeated readings of a text are more effective with promoting comprehension and recall than massed repeated readings (Krug, Davis, & Glover, 1990).

In addition to repeated readings of a text, Guzzetti et al. (1993) meta-analysis revealed that conceptual change can be facilitated when the refutation text is read in conjunction with other instructional activities. Group discussions addressing the main ideas of a text have been shown to be an effective intervention for promoting text comprehension and recall of main ideas (Anderson, Chinn, Waggoner, & Nguyen, 1998; Beck, McKeown, Sandor, Kucan, & Worthy, 1996; Chinn, 2006; Eeds & Wells, 1989). Group discussions are intended to increase the reader's engagement with the text (Almasi, McKeown, & Beck, 1996; Beck & McKeown, 2006; Chinn, Anderson, & Waggoner, 2001). This deeper engagement with the text may in turn increase the likelihood of conceptual change (Dole & Sinatra, 1998).
In the following sections I review the research concerning the benefits of repeated reading of texts on individuals’ comprehension and recall of the information presented. Next, I present descriptions of three seminal group discussion formats used to facilitate young students' understanding of text information. Research in support of these instructional activities is also reviewed.

Rereading

*Effects of reading text repeatedly.* Amlund and colleagues (1986) investigated whether the repeated readings would improve the quality and quantity of recall and error persistence of reading a text passage one, two, or three times. Graduate students were given an expository text passage containing 12 main-idea units and 145 detail units. Participants were randomly assigned to one of three conditions: read text once, read text twice, or read text three times. Immediately after reading the text, participants’ recall of main ideas and details were assessed with cued and free recall items. Participants across groups read the text one more time followed by an immediate retest. One week later, participants completed the cued and free recall measures a third time. Participants did not read the text during the second session.

Amlund et al. (1986) findings revealed that on the immediate cued recall tests, participants in the two- and three-read groups outperformed participants in the one-read group. No significant difference was found in performance on immediate cued recall between the two- and three-read groups. The opportunity to reread the passage prior to the second cued recall test revealed no significant differences between groups. This finding suggests that participants in the one-read group benefited more from rereading the text after the immediate recall test than those in the two- and three-read groups. Also,
participants in the two-read group performed better than those in the one-read group on the delayed cued recall test given one week after last the last reading of the text

Analysis of the free recall tests show that participants in the two-read condition outperformed participants in the one- and three-read conditions across all three test occasions (Amlund et al., 1986). Participants in the three-read condition recalled significantly more details than main ideas. The proportion of main ideas to details was not significantly different for those in the one- and two-read groups.

An important finding from Amlund et al. (1986) is that rereading a text twice increases recall of main ideas more than reading the text once or even three times. It may be the case that retention and recall level off after two readings as suggested by the increase of details recalled by participants in the three-read condition.

**Massed and distributed repeated readings.** Krug and colleagues (1990) conducted a study to compare the differences in information recall between massed and distributed repeated readings. It is often the case that text recall is better when a period of time occurs between readings of the same text than when the repeated readings occur at the same time. Krug et al. explain that this phenomenon is referred to as the *spacing effect*.

Krug et al. (1990) hypothesized one possible explanation for the spacing effect is the *deactivation hypothesis*. According to the deactivation hypothesis, “full processing of text will occur only on those learning trials in which readers’ representations of the text are absent from working memory or deactivated at the onset of the reading episode” (p. 366). Moreover, when those representations are activated in the readers’ working memory, the reader is likely to skim the text depending upon the ease of availability of the text information in their working memory.
Krug and colleagues (1990) suggest that text recall is enhanced when students read a text more than one time whether the repetition is massed or distributed. Moreover, distributed reading is more effective than massed reading for text recall. Students may benefit more from reading texts with a lapse of time in between readings rather than rereading the text immediately following the initial reading.

Small Group Literature Discussions

Group discussions provide the forum through which students can have the opportunity to share their ideas and listen to the ideas of others. Through this exchange of ideas, students can construct new conceptions and ways of thinking (Chinn et al., 2001). Small group literature discussions have been shown to facilitate engagement, increase comprehension, and promote critical analysis of the ideas presented in the text (Anderson et al., 1998; Beck & McKeown, 2001, 2006; Eeds & Wells, 1989; Raphael, 1998; McKeown, Beck, & Worthy, 1993). It is through these higher levels of cognitive engagement with the ideas in a text that the likelihood of conceptual change may occur (Dole & Sinatra, 1998).

Promoting engagement through small group literature discussions. In a seminal study, Eeds and Wells (1989) examined the nature of learning during small group literature discussions. Participants for this study included preservice teachers enrolled in a reading practicum course, and 5\textsuperscript{th} and 6\textsuperscript{th} grade students. The preservice teachers led the discussion groups with the elementary students twice a week. The preservice teachers shared a brief overview on each of the available books with the students. The students then selected a discussion group to join. The preservice teachers received training on how to conduct the small group discussions, including an emphasis on releasing control of the
discussion to the students. The purpose for this was to allow the researchers to see how the meaning of the texts would emerge naturally during the discussion, hopefully resulting in “grand conversations” rather than simply recalling facts from the stories.

Eeds and Wells (1989) found that small group literature discussions initially focused on surface level recall of information from the texts including facts about the characters, plot, and setting. However, the findings suggest that students experienced high levels of engagement with the text as they collaboratively constructed a simple meaning of the text and shared personal experiences connected to events in the texts. Over time, the depth of the discussions increased as students made hypotheses and predictions about what they were reading. As part of this process, students would seek information from the text to verify or discount those hypotheses. In addition, students evaluated and critiqued the ideas and events in the texts. Each of these characteristics of the small group discussions suggests a high level of engagement with the information in the texts.

Although the texts used for discussions in Eeds and Wells (1989) study were novels, it is the level of engagement demonstrated by students that is of interest to the current study. The findings suggest that small group discussions around a text can facilitate deep engagement with the information presented. The characteristics of collaboratively constructing meaning of a text, stating hypotheses and verifying those hypotheses are each useful strategies in conceptual change pedagogy. Also beneficial for conceptual change learning is the thoughtful evaluation and critiquing of ideas. Eeds and Wells provide evidence that small group discussions can foster this type of cognitive engagement among elementary students.
Further information on the nature of engaged reading during small group discussions is provided by Almasi and colleagues (1996). Participants for this year-long qualitative study included two fourth-grade teachers and their students. Data collection involved observations and video tapings of Questioning the Author (QtA) (Beck & McKeown, 2001; 2006; McKeown, 1993) discussions, semi-structured interviews with the teachers and students, and teacher journals which contained their reflections on the nature of student engagement during the discussions. The researchers met with the teachers on a weekly basis and provided two in-service workshops on implementation of QtA.

Four central features of QtA include: a) reinforcing the notion that the author is fallible which may result in a text that is not clear or complete; b) open-ended, goal-directed teacher queries intended to help students develop a meaningful representation of the ideas presented; c) engaging in a discussion as the text is read; d) developing a discussion that encourages students to grapple with the ideas as they construct meaning (Beck & McKeown, 2006). Each of these features is described in more detail in a later section of this chapter.

Almasi et al. (1996) study suggests that engagement increased as students connected ideas from the text with their background experiences or used information from the text to support their ideas and verify or reject predictions. Students reported higher levels of engagement during discussions when students initiated questions and selected topics for discussion. Similarly, student engagement increased when they were allowed to share their own ideas, as well as when other students shared their ideas, during discussions. The findings also suggest that offering arguments and counterarguments
increase engagement as students gather information from the text and their prior experiences to support their claims.

Moreover, findings revealed that text format can influence the degree to which a reader will engage with the text. The texts used by the participants in Almasi et al. (1996) were narrative trade books. Texts that were perceived by the reader to be interesting, personally intriguing, or exciting were linked with higher levels of engagement. This finding is similar to findings by Hynd (2003) regarding increased engagement with refutation text due to its format. Recall that participants in Hynd’s study explained that they preferred the refutation text over traditional expository text because the refutation text was written in a clear, concrete, and compelling format.

A variety of small group literature discussion formats exist. A full review of each of those formats is beyond the scope of this review. The small group format selected for the present study was purposefully selected because it has been identified by researchers as fostering deep cognitive engagement (Almasi et al., 1996; Beck & McKeown, 2001; 2006). Recall that deep levels of engagement between the learner and the message in a text increase the likelihood of change (Dole & Sinatra, 1998).

**Questioning the Author**

Questioning the Author (QtA) (Beck & McKeown, 2001, 2006; Beck, McKeown, Sandor, Kucan, & Worthy, 1996) is an instructional intervention for promoting deeper levels of cognitive engagement with ideas presented in texts. Engagement with the ideas presented in a text is facilitated through collaborative discussions between teacher and students. The collaborative meaning-making discussions take place as the teacher and students read the text together, pausing at key points in the text to grapple with ideas in
order to make sense of the ideas presented. Questioning the Author allows students the
opportunity to connect their topic-relevant knowledge with what the author has written as
well as to what other students know, and then use that information in constructing a
collaborative understanding of the text (McKeown et al., 1993).

The intent of QtA is to have students challenge the perceived authority of a text
by questioning the ideas presented and critically reflect on the meaning of those ideas.
Building a shared understanding of the text is accomplished through the use of Queries
and Instruction (Beck & McKeown, 2006; Beck et al., 1996). Queries are intended to
help students retrieve information from a text as they collaboratively construct the
meaning of a text. In addition, queries are used to expand the discussion around the text
by incorporating students’ responses into the discussion. Queries can also serve to check
students’ prior knowledge of key words in the text.

The types of queries posed by the teacher in QtA include initiating queries that
are intended to start a discussion of the text and focusing queries designed to clarify ideas
in the text and provide guidance for further discussion. An example of an initiating query
is “What is the author trying to say?” while a focusing query is “What is the author trying
to tell us here?” (Beck et al., 1996, p. 389). The purpose of queries is to engage students
in exploring ideas in the text rather than to check on students’ recall of information
explicitly stated in the text. Query selection is flexible and determined by students’
responses as the discussion proceeds.

The teacher decides what portions of the text should be read prior to posing a
query and engaging students in collaborative discussion about the key ideas. In
determining the amount of text to read before a query is posed, the teacher considers the
importance and difficulty of ideas presented in a segment of the text (Beck & McKeown, 2006). The queries serve to help students form a coherent representation of the central ideas from that segment of the text as well as how those ideas relate to the text in general. QtA discussions may help students' increase their understanding of the main ideas in the text such that they construct a coherent representation of those ideas (McKeown et al., 1993).

Empirical research on Questioning the Author. Beck and colleagues (1996) conducted a qualitative study to explore the effectiveness of QtA. Participants for the study included two teachers, one who taught social studies and one who taught language arts/reading and their 23 fourth-grade students in a small parochial inner-city school. The students in this study were predominantly African American from lower SES families. The study took place over the course of one school year in both the social studies class and the language arts/reading class.

The lesson analysis revealed that the teachers' queries shifted from focusing on students' direct recall of text information to queries that prompted students to think about and construct meaning from the text. The format of the discussion also changed over time to include more of students' responses into the discussions through paraphrasing or refining their ideas. According to Beck et al. (1996) this process fostered students' engagement and text comprehension because their ideas were used as grist for developing the discussion.

This study also revealed that the amount of teacher talk decreased and the amount of student talk increased in the discussions over time through QtA lessons. This increase was especially noticeable in the social studies lessons where the amount of student talk
more than tripled over the course of the year. Beck et al. (1996) suggest that this increase may have been due to teachers discussing ideas they found confusing as well as how they grappled with those ideas. As a result, students' may have integrated similar ways of sharing their reactions with the text during the discussions.

Further, Beck et al. (1996) found that students’ comments during QtA discussions became more complex over time. Students’ questions gradually became more directed toward extending the ideas in the texts thus increasing their ability to construct meaning from the text. In addition, students became more responsive to their peers’ contributions during discussion as opposed to responding mainly to the teacher’s queries.

Students’ ability to monitor their reading comprehension also improved with time. Initially, nearly three-fourths of the students failed to monitor their comprehension while reading. Posttests revealed that more than three-fourths of the students were successfully monitoring their comprehension. These results suggest that students were internalizing the skills needed to construct meaning and monitor their understanding of texts. Beck et al. (1996) note that these results cannot be linked with certainty to QtA because of a lack of a control group. However, the growth in students’ text comprehension abilities coincides with their involvement in QtA lessons.

Finally, student interviews conducted at the end of the study revealed two common themes: the importance of collaboratively constructing meaning of a text and realizing that text comprehension can be impeded if the author did not write the text clearly. Beck et al. (1996) suggest that QtA helped students begin to develop confidence to agree or disagree with the author’s ideas, their peers and teacher’s ideas, as well as their own. These are all critical factors that are likely to make QtA a discussion strategy
that could facilitate students' ability to grapple with controversial information presented in a refutation text.

Beck and McKeown (2001) have continued to conduct qualitative research studies investigating the instructional approach of QtA. The researchers have implemented and analyzed the implementation of this instructional activity across Grades 3-9 in over 100 classrooms. The content area for these discussions was primarily social studies and history.

An analysis of the data across these 100 classrooms consistently shows that teacher and students' roles during discussions change over time as they integrate QtA into their literacy activities. For example, teachers' questions shifted from surface level recall questions to those that require students to thoughtfully consider and extend the meaning of the ideas in the text. Beck and McKeown (2001) report that teacher questions typically included a focus on why an event happened and how it connected with other information in the text.

In addition, the findings consistently showed that students became more actively involved in the QtA discussions as they often took on the role of initiating questions and comments (Beck & McKeown, 2001). Over time, the students relied less on the teacher to facilitate the discussions. The analyses also revealed that students' responses focused more on integrating ideas and constructing information than on simple recall of information from the text. Deeper levels of engagement with the ideas in the text were made visible with students' connecting ideas, integrating prior knowledge with the new information, and using their own words to convey their thoughts rather than the language
of the author. Each of these factors associated with QtA discussions may help to promote deep cognitive engagement with ideas in a refutation text.

**Present Research**

Researchers have argued that emotions influence the ways in which individual’s process information (Bless, 2000; Forgas, 2000; Lazarus, 1982, 1984; Pekrun, 2006; Zajonc, 1980). In addition, research has shown that conceptual change processes have an affective component (Linnenbrink & Pintrich, 2002; 2004). Models of conceptual change suggest that cognitive conflict, often associated with negative emotions, is likely to foster deep engagement with the anomalous information (Dole & Sinatra, 1998, Gregoire, 2003; Posner et al., 1982). This deeper engagement may in turn foster conceptual change (Dole & Sinatra, 1998; Murphy, 2007). What has not yet been investigated is whether positive emotions can also promote conceptual change. More specifically, research has not examined the influence of the two dimensions of emotions, valence and activation (Pekrun et al., 2002), on controversial conceptual change.

As demonstrated by the literature review conceptual change can be promoted through refutation texts (Guzzetti et al., 1993; Hynd et al., 1994; Murphy, 2001). Elementary students through undergraduate students who read refutation texts outperformed students who read expository texts on topics such as projectile motion (Alvermann & Hynd, 2001; Hynd, 2001; Hynd et al., 1994), energy (Diakadoy et al., 2003), and photosynthesis (Mikkilia-Erdmann, 2002). Researchers have also shown that dual-position texts can promote change on controversial topics including the origin of life (Limon & Carretero, 1997 as cited in Limon, 2003) and HIV-AIDS (Kardash & Scholes,
further, increased levels of cognitive engagement with ideas in the text can be facilitated through rereading (Krug et al., 1990) and through small group discussions (Beck & McKeown, 2006; Anderson et al., 1998).

As noted previously, past research has shown that refutation texts are more effective than expository texts in promoting conceptual change (Broughton, et al., 2007; Guzzetti et al., 1993). Consequently, this study did not look at text type (refutation, expository) to compare levels of change in students’ NOS beliefs, attitudes about Pluto’s reclassification, and concepts about planets. Rather, this study focused on whether refutation text can be effective with emotionally laden information through rereading and rereading enhanced with small group discussions. Furthermore, the anticipated number of participants for this study was relatively small (n = 62) which would not provide sufficient power to conduct the study as outlined with the addition of text structure differences.

Purpose of the Study

One goal of this study was to investigate the nature of emotions engendered when learning about a controversial topic in science. Using Pekrun et al. (2002) as a framework, this study examined the valence (positive/negative) as well as activation (activating/deactivating) of emotions students’ experience and the influence those emotions may have exerted on the change process while studying about the nature of science and Pluto’s dwarf-planet status.

A second goal of this study was to examine whether rereading a refutation text or rereading a refutation text with small group discussions about the text promoted change in students’ beliefs, attitudes, and conceptions. According to the CRKM (Dole & Sinatra,
1998) higher levels of engagement with a message increases the likelihood of change. Rereading may have increased cognitive engagement. Further, even deeper levels of engagement may have resulted from rereading and discussing the text.

Additionally, past research investigating students' NOS beliefs have used students' beliefs as a predictor of whether belief change is likely to occur (Mason, in press; 2001; Mason & Gava, in press). This study adds to the existing literature by investigating whether change in students' beliefs about the nature of science can be promoted through rereading the refutation text alone or rereading the text plus small group discussions.
CHAPTER 3

METHOD

Design of the Study

In the first phase of this mixed methods study, quantitative data about students’ NOS beliefs, students’ attitudes towards the reclassification of Pluto, and students’ emotions regarding Pluto’s change in planetary status were measured. In addition, qualitative data was collected during the small group discussions centered on the changing nature of science and Pluto’s new status. This information was analyzed to see if students’ responses move toward a coherent representation of the central ideas presented in the text as well as whether belief change, attitude change, and/or conceptual change occurred through the discussions. In the second phase, qualitative semi-structured interviews were used with four participants to explore the influence of emotions on controversial conceptual change. The qualitative data provided insights to the participants’ perspectives that the quantitative data may not have necessarily reflected.

Participants

Participants for this study were 62 fifth and sixth grade students enrolled in a private school located in the intermountain West. Students at this school came primarily from White, upper-middle class families. Of those who completed the Demographics
survey, 24 students were fifth graders and 31 students were sixth graders with approximately the same number of males \((n = 27)\) and females \((n = 28)\). Students’ ages ranged from 10 to 12 years, with a mean age of 10.84. Students were primarily Caucasian \((n = 43)\), with Asian American \((n = 5)\), and Hispanic \((n = 2)\). Three students reported speaking English as a second language.

All students read the refutation text about the certainty and development of scientific knowledge and the change in Pluto’s planetary status (Appendix F). Students in both classrooms were randomly assigned to one of two reading conditions: rereading plus small group discussion about the text (experimental) or rereading only (control).

Measures

I received approval through the UNLV Social/Behavioral Institutional Review Board (IRB) prior to conducting this research. Approval was granted on September 5, 2008, Protocol #0708-2430. In the first phase of this mixed method design, I administered measures to examine students’ emotions and attitudes toward the reclassification of Pluto, as well as their level of understanding of scientific concepts and the nature of science beliefs, all of which are explained in the following.

*Emotions about Pluto’s Reclassification*

Students’ emotions towards the reclassification of Pluto to a dwarf planet were assessed using the Emotions about Pluto’s Reclassification survey (EPR). Two versions of the EPR were constructed specifically for the present study. The EPR surveys were developed in collaboration with a university professor whose primary line of research is emotions and motivation in education. The pre-reading EPR survey assessed students’
emotions relative to when they first found out about Pluto's reclassification (Appendix A). The post-reading EPR survey assessed students' emotions after they read the text explaining why Pluto was reclassified (Appendix B).

The EPR was constructed using The Class-Related Emotions Scales (CRES) (Pekrun et al., 2005) as a framework. The CRES is intended to identify students' emotions at the general classroom level. Alpha reliability coefficients of the CRES have ranged from .79 to .93 in previous research. For purposes of the present study, it was determined that the level at which the CRES measures emotions is too general. As a result, I constructed the EPR to measure emotions specifically related to the topic of Pluto's reclassification.

I used the three categories of emotions on the CRES (Pekrun et al., 2005) for the EPR. These categories include positive activating emotions (enjoyment, hope), negative activating emotions (anger, anxiety), and one negative deactivating emotion (boredom). These categories were selected from the CRES because they characterize the emotions students are most likely to experience in relation to the change in Pluto's status.

The two versions of the EPR were similar in format. Each version contained the same list of emotions presented in identical order. Additionally, each version emphasized that people may have experienced a variety of emotions related to the change in Pluto's status.

Differences between the two versions of the EPR are found in the instructions. The instructions for the pre-reading EPR asked students to think back to how they felt when they first found out that Pluto is no longer a planet. In contrast, the instructions in
the post-reading EPR asked students to indicate how they are feeling “right now” (immediately following the reading of the text) about Pluto’s reclassification.

Students rated their emotional experiences on a 5-point Likert scale (1=strongly disagree to 5=strongly agree). Students recorded their responses on their individual surveys. Scoring of the EPR was calculated by summing the students’ responses on each subscale and taking their mean.

*Attitudes about Pluto Survey*

Students’ attitudes about the change in Pluto’s planetary status were assessed with the Attitudes about Pluto Survey (Appendix C). The survey consisted of 5 Likert-scale items ranging from 1=strongly disagree to 5= strongly agree. Higher responses indicated higher levels of acceptance. Items were developed using Kardash (in progress) *Pre-reading beliefs about cloning* survey as a framework. Examples of items include “The scientists’ decision to change Pluto from a planet to a dwarf planet was a good one,” and “Pluto should remain a planet.” For data analysis, Items 2 and 5 were reverse coded so that higher scores reflected greater levels of acceptance towards the change in the definition of planets as well as Pluto’s dwarf-planet classification.

*Concepts about Planets Assessment*

Students’ conceptual knowledge about planets and Pluto was assessed with the Concepts about Planets Assessment (Appendix D). The assessment consisted of six open-ended questions. This format was similar to that used by other researchers investigating conceptual change (Broughton, Sinatra, & Reynolds, 2006; Hynd, 2001; Hynd, Alvermann, Qian, 1997; Mason, 2001, in press). Examples of items included, “How
many planets are in our solar system?” and “Why did scientists change the definition of planet?”

**Beliefs about the Nature of Science**

Students’ beliefs about the nature of science were measured with an abbreviated version of the Beliefs about the Nature of Science (Conley et al., 2004) (Appendix E). The original 26-item instrument measured elementary students’ changes in beliefs in science over time in four dimensions: source, certainty, development, and justification of science knowledge. Items were rated on a 5-point Likert scale (1=strongly disagree, 5=strongly agree).

More recently, Mason (in press) abbreviated the survey to 12-items that measure students’ beliefs about the certainty (i.e. “Scientific knowledge is always true”) and development of scientific knowledge (“New discoveries can change what scientists think is true”). These two scales are the most relevant to the focus of the current study. The alpha reliability coefficient of the adapted version of the instrument is .73 (Mason, in press). For data analysis, the certainty scale was reversed so that higher scores reflect more constructivist beliefs about the nature of science.

**Refutation Text**

The effects of belief change, attitude change, and conceptual change were examined through the use of a refutation text (Appendix F). The refutation text explains the changing nature of science, the role of evidence in making scientific decisions, and the history of Pluto’s status as a planet. The text consisted of 556 words, 8 paragraphs, with an average of 10.9 words per sentence. Flesch-Kincaid readability analysis of the text showed that it was at the 6.4 grade reading level. The passage was reviewed by three
expert judges: two sixth-grade elementary teachers and one university professor whose primary line of research focuses on young students’ NOS beliefs and their influence on science learning. Revisions to the text passage were made based upon the expert judges’ recommendations.

Information magazine articles were used in writing the text (National Geographic News, 2006; Scientific American, 2006; Time for Kids, 2006). In addition to refuting students’ beliefs about the nature of science and their attitudes about Pluto’s planetary status, the text included information on the definition of a planet. The purpose for including the new definition of a planet was to change students’ conceptions of planets as well as to help them understand the International Astronomical Union’s (IAU) decision to generate the new definition (IAU, 2006).

The text consisted of two refutation segments. The first segment described the changeability of science knowledge. The second segment provided information on the reclassification of Pluto as a dwarf-planet (IAU, 2006). This topic was purposefully selected because of its controversial nature (Adler, 2006). Each refutation segment was written so that the first sentence in that segment activated the participants’ prior knowledge by stating a common misconception (Hynd, 2001). The second sentence explicitly refuted that misconception. The sentences and paragraphs that followed the refutation sentences provided the scientific explanation related to that topic.

**Interviews**

Eight semi-structured interview questions addressed participants’ initial attitudes towards the reclassification of Pluto, initial emotional responses to the change in planetary status of Pluto, and their beliefs about the nature of science (See Appendix G).
Questions also addressed participants' beliefs and attitudes after having read the text. These questions included participants' emotions towards Pluto's status as a dwarf planet, participants' acceptance of the new definition of planet as well as Pluto's new classification, the changing nature of science, and the role of evidence in making scientific decisions.

Demographics and Reading Level

Student demographics were collected (Appendix H). Items included gender, age, ethnicity, primary language, and second language (if any). I was unable to gain access to the students reading levels through the principal. Therefore, reading levels were not included as a covariate in the analyses.

Procedure

Pilot Testing of Instruments

All instruments were piloted and examined for potential revision prior to administration of the study. In addition, the time allotted to participants to read the text was determined based on the findings from the pilot study. Participants for the pilot study were sixth grade students enrolled in an elementary school ($n = 24$). The pilot test occurred over two sessions, replicating Session 1 and Session 2 of the main dissertation study.

Session 1. The researcher read aloud the background knowledge passage, The Big News (Appendix J) to the participants. After the read aloud, participants completed the pre-reading EPR, the Attitudes about Pluto Survey, the Concepts about Planets assessment, and the Beliefs about the Nature of Science survey (Conley et al., 2004) as
pre-assessments on Day 1. Students also completed the demographics survey. The researcher read aloud the instructions and items on each survey while the students individually marked their responses on the corresponding survey.

**Session 2.** Session 2 (Day 3) occurred two days after Session 1. All participants read the refutation text individually and silently. Students were given 15 minutes to read the text. The text passages were then collected by the researcher. Next, students completed the post-reading EPR, Attitudes about Pluto Survey, the Concepts about Planets assessment, and the Beliefs about the Nature of Science survey (Conley et al., 2004) as posttests. The researcher read aloud the instructions and items for each survey as students responded individually on their corresponding surveys. The surveys were collected from each student by the researcher at the end of the session.

Data from the pilot testing was analyzed and used to inform the researcher of areas for revision within the refutation text, both versions of the EPR, the Attitudes about Pluto survey and the Concepts about Planets assessment. Items on the Beliefs about the Nature of Science were not adjusted as this instrument had previously been validated (Conley et al., 2004; Mason, in press).

**Data Collection at the Research Site**

Data collection occurred over a two week period during 4 one-hour sessions per classroom. Within each classroom, students were randomly assigned to either the experimental group (rereading plus discussion) or the control group (rereading only). To ensure confidentiality, students were given a five-digit identification number.

To help ensure that students clearly understood the items on the surveys, the directions and items for each survey were read aloud by the researcher at each
administration (pre-, post-, and delayed posttest). Students followed along on their individual copies of the surveys, marking their response to each item as it was read aloud by the researcher.

**Phase I.** Prior to Session 1, students were given the Informed Assent and Informed Consent forms. Students were asked to take these two forms home and review them with their parent(s). All students enrolled in fifth and sixth grades at the research site participated in the instructional activities. However, parents and students had the option to have their responses omitted from the data analyses. Parents were asked to sign and return the Informed Consent form. Parents indicated on the Consent form whether they gave permission to have their child’s responses on the instruments, small group discussions, and interviews included in the data analyses. Students were asked to sign and return the Informed Assent form indicating whether they gave permission to have their responses included in the data analyses as well. Choosing to have a student’s responses included in the data analyses in this study was voluntary. If the student did not receive parental permission to have their responses included in the analyses, or if the student chose not to have their responses included, the responses were excluded from the analyses.

At the beginning of Session 1 (Day 1), students were asked to turn in their signed Informed Assent and Informed Consent forms. All students were assigned a five-digit participant identification number.

Next, participants completed the demographics survey. The researcher then read aloud the passage *The Big News* to the participants. Following the read aloud, students completed the pre-reading EPR, the Attitudes about Pluto Survey, Concepts about Planets
assessment, and the Beliefs about the Nature of Science Survey (Conley et al., 2004) as pre-assessments. Session 1 took approximately 1 hour.

Session 2 (Day 3) occurred two days after Session 1. All participants read the refutation text. Students read the passage individually and silently. Students were given 15 minutes to read the text. The time allotted to read the text was determined through the pilot test. The text passages were collected by the researcher. Next, students completed the post-reading EPR, marking their responses to each item as it was read aloud by the researcher. At the end of the session the surveys were collected from each student by the researcher.

Session 3 (Day 4) took place one day after Session 2. Participants in the experimental condition engaged in small group discussions based on the Questioning the Author (Beck, McKeown, Sandora, Kucan, & Worthy, 1996) style small group discussion. A brief description of these small group discussions is presented in the following section. Participants in the control group reread the text independently at their desks. At the conclusion of their respective activities, all students completed the post-reading EPR, the Attitudes about Pluto survey, Concepts about Planets assessment, and the Beliefs about the Nature of Science survey (Conley et al., 2004) as posttest assessments.

QtA was purposefully selected for the small group discussions because the teacher serves as facilitator and guide throughout the discussion (Beck & McKeown, 2006; Chinn et al., 2001). This is in contrast to other small group discussion formats in which the students assume the role of discussion facilitator (Anderson et al., 1998; Chinn
et al., 2001; Raphael, 1998). Having the researcher assume the role of facilitator ensured that the discussion stayed focused on the central ideas of the refutation text.

A total of two groups per class were selected to participate in the small group discussions. The experimental group and the control group had approximately equal numbers of participants. Small groups consisted of 8 to 9 students per group.

The small group discussions took place in a room separate from the regular classroom. Discussions lasted approximately 20 minutes and were audio recorded. The data from each session was transcribed for analysis.

The discussion format was semi-structured, and included questions such as “So what is the author trying to tell us?” or “What do you think the author wants us to know?” The queries used during QtA discussions were intended to support students’ building a coherent understanding rather than retrieving information from the text. Appendix I shows where the refutation text was segmented, the queries for each segment, and the purpose for using the queries at that particular point of the text. The queries were not rigid, meaning that different queries were used depending upon students’ responses. In an effort to help students connect text ideas with those shared during the discussion, students’ responses were integrated into the queries.

Students’ prior knowledge was elicited throughout the small group discussion. This was an important component of the QtA discussion because it may have helped students recognize the differences between their existing ideas and the new information presented in the text. The likelihood of change in beliefs, attitudes, and conceptions may have increased as students compared and contrasted the differences between their prior
knowledge and the information in the text (Chinn & Brewer, 1993; Chi, in press; Dole & Sinatra, 1998).

Session 4 (Day 18) took place two weeks after Session 3. Students completed the Attitudes, Concepts, and Beliefs about the Nature of Science survey (Conley et al., 2004) as delayed posttests. The researcher read aloud the directions and items for each survey as students followed along on their individual copies marking their responses. Students did not complete the EPR at delayed posttest because emotions must be measured in the moment and too much time had lapsed since they reread text.

Phase II. I completed an initial analysis of the data to determine the overall degree of change per student. Degree of change was calculated using the difference scores from pretest to posttest on the NOS beliefs, APR, and Concepts about planets measures. From this analysis I selected two students from each class, one with high degree of change and one with low degree of change to participate in the interviews. The interviews occurred five days after Session 3. The purpose of these interviews was to further explore the influence of emotions on the change process of students' NOS beliefs, attitudes towards Pluto's reclassification, and concepts about planets. The interviews took place outside of the regular classroom and lasted approximately 15 minutes. Interviews were audio recorded. In addition, the researcher recorded student responses in a notebook.

Table 1 provides a description of the timeline of this study as well as the data collection and analysis processes.
CHAPTER 4

RESULTS AND ANALYSIS

Introduction

In this chapter I present a description of the data analyses and results for this study. I begin by presenting the description of the participants as well as a discussion of the preliminary analyses. A detailed discussion is provided on the quantitative analyses related to emotions and NOS beliefs, attitude, and conceptual change. I also provide a description of the quantitative analyses used to examine the learning effects based on the intervention. The qualitative analyses are also described including the componential and litany analyses used to provide a fine-grained analysis of students' responses.

Participants

The participants for this study were fifth grade and sixth grade students enrolled at a private Catholic school located in the Western U.S. (n = 62). Students who attend this school are primarily from upper middle-class families. Participants were predominantly Caucasian (69%), and, across grade levels, spoke English as their primary language, with three students indicating they were fluent in a second language. Students' ages ranged from 10 to 12 years of age, with a mean age of 10.84 years. Participants' demographic characteristics are presented in Table 2. Seven participants did not complete the demographic survey so their information is not included in Table 2. Participants in both
classrooms were randomly assigned to either the experimental group (reread plus small group discussions) or to the control group (reread only).

The decision to use both the fifth and sixth grade classrooms at this particular school was based on information from my contact person at the school that the fifth grade students were an exceptionally performing class. Data from Beliefs about NOS, Attitudes about Pluto's Reclassification, and Concept's about Planets surveys, at Time 1, Time 2, and Time 3, were first compared to see if there was justification for combining the two classes.

A series of multivariate analyses of variance were conducted to test the equivalence of Grade 6 students with Grade 5 students. The alpha level was set a priori at .001. Table 3 displays the significance values of the Box's and Levene's tests of homogeneity of variance for these analyses. With the exception of Concept Item 3 at pretest (p = .000) and Concept Item 4 at pretest (p = .000), Box's test of equality of covariances revealed no significant difference between groups, as did Levene's test for equality of variances (all p > .001).

I conducted an independent-samples t-test to determine whether the differences between fifth and sixth graders were significant on Concept Items 3 and 4 at pretest because these items failed to pass the homogeneity of variance analyses. The results showed that no significant differences existed between the two groups at pretest on Item 3, t(50) = 1.59, p = .118. However, the t-tests revealed significant differences existed between fifth and sixth graders on Item 4, t(50) = 2.64, p = .011.
The means and standard deviations for the Concept Items at pretest between the two classes are shown in Table 4. In general, no significant differences were found between the two groups, so the two classes were combined for further analyses.

Preliminary Analyses

Measures

Emotions about Pluto’s Reclassification (EPR). I used Pekrun et al. (2002) as the initial framework for the EPR. Recall that Pekrun and colleagues explored undergraduate students’ emotions at the general classroom level. Confirmatory factor analysis conducted by Pekrun et al. showed that the emotions identified in the exploratory study formed four clusters: positive activating, positive deactivating, negative activating, and negative deactivating.

For the present study, I modified Pekrun et al. (2002) Academic Emotions Questionnaire in order to assess students’ emotions related to a specific topic, the reclassification of Pluto to a dwarf planet. The clustering of emotions experienced by fifth and sixth grade students in relation to a specific topic may be different from those identified by undergraduate students regarding learning in general contexts. I constructed the EPR using the 18 academic emotions originally identified by Pekrun and colleagues. The order of emotions on the EPR was randomized by the process of writing the emotions on individual sheets of paper and pulling them out of a sack.

Correlational analyses of the EPR at pretest, post first reading, and post rereading were used to determine the emotions subscales for the present study. A factor analysis of the emotions was not appropriate for the present study based on the size of the group.
Based on the correlational analyses, two emotion subscales were identified, a) positive emotions (joy, glad, happy, excited, bored) and b) negative emotions (uneasy, worried, surprised, disappointed, mad, scared, irritated, sad, upset, nervous, angry, frustrated, annoyed). The correlations among emotions at pretest are presented in Table 5.

The analyses showed a moderate, positive correlation between bored and the positive emotions joy ($r = .353, p < .05$), happy ($r = .464, p < .05$), and excited ($r = .386, p < .01$). Bored is not a positive emotion (Pekrun et al., 2002) so it was dropped from further analyses. The distinction among activating and deactivating emotions was not born out in these analyses. Due to the low number of participants in the study and the inability to run a factor analyses, the two dimensions could not be confirmed. The factor analysis may have been able to detect the distinctions between activating and deactivating emotions.

The correlations of emotions at post-first reading and post-second reading were similar to those of emotions at pretest, with emotions tending to cluster together in the same groups across all three test times.

After determining the subscales for the positive and negative emotion subscales, I checked the reliability of the scales at pretest, posttest, and delayed posttest. Cronbach alpha on the positive emotion subscale reflects moderate levels of internal consistency: Time 1 $\alpha = .82$, Time 2 $\alpha = .86$, and Time 3 $\alpha = .77$. The negative emotion subscale showed consistently higher alpha values than the positive emotion subscale. Reliability for the negative emotion subscale at pretest was .89, at posttest was .90, and at delayed posttest was .92.

Normality of the two emotion subscales was checked by looking at the skewness and kurtosis values at Time 1, Time 2, and Time 3. Skewness was low for the positive
emotion subscale across all three time intervals, pretest .37, posttest .16, and at delayed posttest .54. Similarly, the positive emotion subscale had moderate values of kurtosis at pretest .66, posttest .63, and delayed posttest .64. These values reflect a fairly normal distribution for the positive emotion subscale. The negative emotion subscale also revealed low values for skewness across the three time intervals with values at pretest -.49, posttest -.14, and delayed posttest .25. Kurtosis values were relatively moderate with values at pretest -.41, posttest -.83, and delayed posttest -.69. Again, these values on the negative emotion subscale reflect a relatively normal distribution that is slightly flat with some cases in the extremes.

*Nature of Science Beliefs.* In this study, I used the abbreviated version of Conley and colleagues (2004) instrument for measuring elementary school students’ epistemic beliefs about science. The NOS measure consisted of 12 items related to two scales, development of knowledge ("New discoveries can change what scientists think is true") and certainty ("Scientific knowledge is always true"). Items on the certainty scale were reversed. Higher scores on both scales reflect more constructivist beliefs about the nature of science.

I used Cronbach’s alpha to check the reliability of the NOS beliefs measure at pretest .77, posttest .86, and delayed posttest .87 indicating a moderate level of internal consistency for this instrument over time with this sample. The means and standard deviations for each administration of the NOS measure are presented in Table 8. I also created mean score variables for the NOS beliefs instrument at pretest, posttest, and delayed posttest. I calculated the mean score variables by summing students’ responses on the individual items and then dividing that sum by the total number of items on the
survey. For example, the NOS beliefs survey consisted of 12 questions, so each student’s summed score was divided by 12. These mean score variables were used for all subsequent analyses.

In analyzing the NOS beliefs measure for normality of distributions, I checked for outliers on the mean score variables at Time 1, Time 2, and Time 3. An outlier was any score three standard deviations above or below the mean. No outliers were identified from this analysis. I checked for skewness and kurtosis with the NOS beliefs measure. Skewness values ranged from .73 at pretest, .15 at posttest, -.08 at delayed posttest, reflecting a fairly normal distribution. Similarly, kurtosis values reflected a weak normal distribution with values at pretest .30, posttest -1.16, and delayed posttest -.99.

*Attitudes about Pluto’s Reclassification.* I constructed the Attitudes about Pluto instrument to assess students’ acceptance of the reclassification of Pluto to a dwarf planet. Item 2 (“Pluto should remain a planet”) and Item 5 (“Scientists should accept Pluto as a planet”) were reversed so that for each item, higher scores reflected greater acceptance of Pluto’s reclassification to a dwarf planet. Reliability of the Attitudes about Pluto’s Reclassification (APR) instrument was determined using Cronbach’s alpha. The means and standard deviations for each item as well as the alpha coefficients for each administration of the APR are presented in Table 6. These coefficients were acceptable, ranging from .92 to .94.

I then created mean score variables for the APR at pretest, posttest, and delayed posttest. The mean score variables were created by summing students’ responses on the individual items and then dividing that sum by the total number of items on the respective survey. For example, the APR consisted of 5 questions, so each student’s summed score
was divided by 5 to create their mean score. These variables were used for all subsequent analyses.

Next, I analyzed the APR at Time 1, Time 2, and Time 3 for outliers. The means and standard deviations are displayed in Table 6. All scores that were three standard deviations above or below the mean were considered outliers. No outliers were identified on the APR at pretest, posttest, or delayed posttest. I then examined the APR for skewness and kurtosis at pretest, posttest, and delayed posttest. Skewness values of the APR were pretest .24, posttest -.20, and delayed posttest -.35. These values are relatively low and reflect a weak normal distribution. Kurtosis values on the APR were -.62, -1.16, and -.94 at Time 1, Time 2, and Time 3 respectively. The kurtosis values at Time 1 and Time 3 were less than 1, indicating that the distributions were approximating normality. At Time 2 the kurtosis value exceeded an absolute value of 1, though only slightly. Based on this data, I conducted the remaining analyses of the APR assuming a normal distribution.

*Concepts about Planets.* I constructed the Concepts about Planets instrument for the present study. This measure consisted of six open-ended questions to ascertain students’ conceptions of planets (Questions 1, 2), Pluto’s reclassification (3, 4, 5) and why scientists changed the definition of planet (6). Students’ responses for the items on the Concepts instrument were scored on a rubric: 0 for non-scientific, 1 for scientific, not elaborated, and 2 for scientific, elaborated. For example, for Item 5, “Why do scientists no longer call Pluto a planet?” the answer “I think that scientists think Pluto is a meteorite or asteroid from Saturn’s ring” scored a 0. The answer “The scientists no longer call Pluto a planet because of its size” scored a 1. The answer “Because of its size, shape, and
orbit they think it is a dwarf planet" scored a 2. Answers were coded by the same two independent raters. Each rater read and scored answers independently. Inter-rater agreement, calculated as the percentage of agreement on the total of the answers was 82%. All disagreements were resolved through conference.

I used Cronbach's alpha to check the reliability of the instrument at pretest .25, posttest .20, and delayed posttest .36. These low reliability coefficients indicate that this instrument did not have internal consistency with this sample. Due to the low reliability levels of the Concepts about Planets survey, I decided to see whether omitting Items 1 and 2 (give the number of planets, write the planets names) would improve overall alpha since these two items were more closely related to factual recall than to conceptions about planets and the new definition of planet. Alpha levels improved slightly at pretest .40, posttest .48, and delayed posttest .47. However, these values were still low, continuing to reflect low internal consistency for this measure.

In reconsidering the items, I determined the items did not form a scale but rather assess different concepts. For example, Item 1 stated, “List the planets are in our solar system,” and was intended to tap into student's concepts about the number of planets in our solar system. In contrast, Item 5 asked, “Why did scientists change the definition of planet?” with the purpose of eliciting students' concepts about scientists' rationale for rewriting the definition of planet. These items are clearly addressing different concepts. Therefore, when I conducted the linear regressions between emotions and conceptions, I ran separate regressions for each individual Concept item. Table 8 shows the means and standard deviations for the individual Concept items at pretest, posttest, and delayed posttest.
I also checked for outliers on the individual items of the Concepts survey. I calculated mean score variables, as described above, at pretest, posttest, and delayed posttest. Outliers were identified as any scores that were three standard deviations above or below the mean. One outlier was identified on the Concepts posttest, participant #25313 with a value of -3.65. This participant was excluded from all further analyses involving the Concepts about Planets posttest. In addition, it is important to note that I set alpha level at .05 *a priori* for each of the analyses described in the remaining sections.

**Influence of Emotions on Change**

The first research question asked: What emotions are engendered among fifth and sixth grade students when learning about a controversial topic in science? To examine this question, I calculated the means and standard deviations for each emotion item on the EPR at pretest. The means and standard deviations are presented in Table 7. As you can see, students experienced a range of positive and negative emotions when they heard about the reclassification of Pluto. I was able to detect those emotions that were present because students rated them as present. The means on positive emotions were rather low, ranging from 1.75 (glad) to 2.02 (joy). Recall that this instrument was based on a 5-point Likert scale, with 1 = *Strongly Disagree* to 5 = *Strongly Agree*. These low means on positive emotions indicate that students, in general, did not experience positive emotions when they heard about the reclassification of Pluto to a dwarf planet. This is further evidenced in the means of the negative emotions. Means on the negative emotions at pretest range from 4.50 (surprised) to 2.84 (angry). These higher mean scores on the
negative emotions indicate that students were generally mad and disappointed with the decision to change Pluto to a dwarf planet.

Two negative emotions had relatively low mean scores in comparison with the remaining negative emotions. These two emotions were scared (1.98) and nervous (2.18). These lower means on scared and nervous suggest that students were less likely feel scared or nervous when they heard about the decision to reclassify Pluto.

*Correlations between Emotions and the Constructs*

Research Question 2 asked, "Do these emotions predict students' a) beliefs about the nature of science, b) attitudes towards the reclassification of Pluto, c) and/or concepts of planets as well as changes on these three constructs? Do these emotions facilitate or inhibit change in students' beliefs, attitudes, and/or concepts about the reclassification of Pluto?" To examine Question 2, I first ran correlational analyses between the two emotions subscales (positive, negative) and the three constructs (NOS beliefs, attitudes, and conceptions of planets and Pluto). I used the Person product-moment correlation when running correlations between the emotions subscales and the APR and the NOS beliefs instruments, as these two instruments consisted of interval/ratio variables. I used the Pearson correlation for all analyses on Concept Items 1 and 2 because these items used an interval scale. The means and standard deviations of the two emotion subscales as well as the NOS beliefs, APR, and Concept Items 1 and 2 at pretest and posttest are shown in Table 8.

I used the Spearman rank-order correlations when I conducted the correlational analyses between emotions and Concept Items 3, 4, 5, and 6. The Spearman rho is appropriate to use when running correlational analyses with ranked data (Cohen, 2001).
Students' responses on Items 3, 4, 5, and 6 were rank ordered on a rubric (0 = non-scientific, 1 = scientific, not elaborated 2 = scientific, elaborated).

The correlational analyses between the Emotions subscales and the individual instruments - NOS beliefs, the APR, and the Concept items - were conducted when the Emotions survey and the individual measures were administered at the same time. Recall that emotions are brief, intense episodes in response to a specific referent (Linnenbrink, 2006; Rosenberg, 1998) and, therefore, must be measured in the moment or as close in time to the episode as possible. Separate correlational analyses were run between Emotions at pretest and the three individual instruments at pretest. I also conducted the individual correlation analyses between Emotions at posttest and the NOS beliefs, APR, and Concept items at posttest.

These correlational analyses did not include data from students' responses for Emotions at post-first reading because none of the remaining instruments were administered at that time. Similarly, I did not run correlational analyses between Emotions and the NOS beliefs, APR, and Concept items at delayed posttest because I did not have students complete the Emotions survey as a delayed posttest. Too much time had lapsed between the rereading of the text and the administration of the delayed posttests.

I began with a Pearson product-moment correlational analysis of the Emotion subscales at pretest and the Beliefs about the Nature of Science instrument at pretest. The results of this analysis can be seen in Table 9. The findings revealed no significant correlations between positive emotions at pretest and NOS beliefs at pretest. Similarly, negative emotions at pretest were not significantly correlated with NOS beliefs at pretest.
Next, I conducted a correlational analysis between emotions at posttest and NOS beliefs at posttest. The findings from these analyses are presented in Table 9. The analyses showed no significant association between positive emotions at posttest and NOS beliefs at posttest. The findings also revealed no significant relationship between negative emotions at posttest and NOS beliefs at posttest.

The correlations between the positive emotions subscale at pretest and the APR at pretest were significant \( (r = .611, p < .01, n = 50) \). The association between negative emotions at pretest and the APR at pretest showed a significant, negative correlation \( (r = -.528, p < .01, n = 50) \). A similar pattern of correlations was found between emotions at posttest and the APR at posttest. Positive emotions were significantly correlated with the APR \( (r = .480, p < .01, n = 52) \). Negative emotions at posttest showed an inverse correlation with the APR at posttest \( (r = -.619, p < .01, n = 52) \). These findings suggest that students with positive emotions reported high levels of acceptance about Pluto's reclassification. Further, students who experienced negative emotions when they heard about the change to Pluto's status reported low levels of acceptance.

The association between emotions at pretest and Concept Item 1 at pretest ("How many planets are in our solar system") was analyzed using the Pearson product-moment correlation. The correlations are presented in Table 9. Positive emotions were not significantly related to students' conceptions of the number of planets in our solar system. The analysis also failed to show a significant relationship between negative emotions at pretest and Concept Item 1 at pretest. Concept Item 1 at posttest was not significantly related to either positive emotions or negative emotions at posttest.
I ran the Pearson correlation analysis between positive and negative emotions at pretest and Concept Item 2 ("Name the planets on our solar system"). Table 9 presents the findings from this analysis. The association between positive emotions at pretest and Concept Item 2 at pretest was not significant. Similarly, the findings were not significant for negative emotions at pretest and Concept Item 2 at pretest.

I conducted a series of correlations to examine the relationship between positive and negative emotions at posttest with Concept Item 2. The findings are shown in Table 9. The relationship between positive emotions at posttest and Concept Item 2 at posttest was not significant. A similar pattern was also revealed for negative emotions at posttest, as these emotions were not significantly correlated with Concept Item 2 at posttest.

Spearman rho correlations were used to analyze the relationship between emotions at pretest and Concept Item 3 ("Should Pluto still be a planet?") at pretest. These correlations are presented in Table 10. The correlations were not significant between positive emotions at pretest and Concept Item 3 at pretest, nor were the correlations significant between negative emotions at pretest and Concept Item 3 at pretest.

Next, I conducted Spearman rho correlations between emotions at posttest and Concept Item 3 at posttest. The findings are shown in Table 10. A significant association was shown between positive emotions at posttest and Concept Item 3 at posttest ($r_s = .343, p < .05, n = 51$). In addition, a significant relationship was shown between negative emotions at posttest and Concept Item 3 at posttest ($r_s = -.437, p < .01, n = 50$). These findings are not surprising when comparing them to the correlations between emotions and the APR. Concept Item 3 assesses students' attitudes about Pluto's planetary status.
The correlations between emotions and Concept Item 3 suggest that students who experienced positive emotions at posttest were likely to report that Pluto should no longer be a planet. Students who reported feeling negative emotions at posttest typically stated that Pluto should remain a planet.

The Spearman rho correlations showed a significant correlation between positive emotions at pretest and Concept Item 4 ("Explain your answer to Question 3") at pretest \( (r_s = .317, p < .05, n = 51) \). Table 11 shows the results. Negative emotions at pretest were not significantly correlated with Item 4 at pretest. Further, the correlations among both positive emotions with Item 4 at posttest revealed no significant associations. This pattern continued with the analysis of negative emotions at posttest and Concept Item 4 at posttest, with no statistically significant relationship revealed.

The analyses also failed to show significant correlations between positive emotions at pretest with Concept Item 5 ("Why is Pluto no longer a planet?") at pretest. The results are shown in Table 11. The findings for negative emotions at pretest did not reveal a significant association with Concept Item 5 at pretest. Again, the correlations between positive emotions at posttest and Item 5 at posttest did not show a significant relationship. The correlational analyses also failed to show a significant relationship between negative emotions at posttest and Concept Item 5 at posttest.

Concept Item 6 ("Why did scientists change the definition of planet?") at pretest also failed to show significant correlations with positive emotions at pretest or with negative emotions at pretest. Table 11 shows the results. Positive emotions at posttest and Concept Item 6 at posttest were not significantly correlated. The analyses also failed to show a significant association between negative emotions at posttest with Item 6 at
posttest. This finding is not surprising, given the lack of significant correlations between the Beliefs about NOS measure and emotions. Concept Item 6 addresses students' concepts about why the definition of planet was changed, which is related to the changing nature of scientific knowledge.

*Regression Analyses using Emotions as Predictors*

I conducted a series of linear regressions to examine whether Emotions at pretest predicted students' NOS beliefs, attitudes about the change to Pluto, and concepts about planets and Pluto at pretest. I ran separate series of ordinal regressions for each individual item on the Concept survey because these are ordinal variables. Table 14 presents the significance levels for the ordinal regression analyses between Emotions (positive, negative) and Concept Items 4, 5, and 6.

A general regression strategy was used to test the hypotheses focused on the valence of emotions to predict students' NOS Beliefs. First, positive emotions and negative emotions at pretest were used as the predictor variables respectively, with the NOS Beliefs mean score at pretest as the dependent variable for both analyses. Table 12 summarizes the results. This series of regression analyses revealed no significant predictive relationships. That is, both positive emotions and negative emotions failed to predict students' beliefs about the nature of science at pretest.

The same regression strategy was used to examine both positive and negative emotions at pretest as predictors of students' attitudes about Pluto's reclassification at pretest. Table 12 summarizes the results. Positive emotions accounted for a significant portion of the variance in students' attitudes, \(F(1, 48) = 28.55, p = .000, \text{ adjusted } R^2 = \)
Similarly, negative emotions were a significant predictor of attitudes at pretest, \( F(1, 48) = 18.58, p = .000 \), adjusted \( R^2 = .264, B = -.754 \).

Separate linear regressions were conducted using Concept Item 1 ("How many planets are in our solar system?") at pretest as the dependent variable and positive and negative emotions at pretest as the predictor variables. Table 13 summarizes the results. The regressions showed that positive emotions at pretest were not significant predictors of students’ knowledge of the number of planets at pretest. Negative emotions at pretest also failed to predict Concept Item 1 at pretest.

The findings of the regression analyses using Concept Item 2 ("List the planets in our solar system") at pretest as the dependent variable and positive and negative emotions as the predictor variables is summarized in Table 13. Positive emotions at pretest were not significant predictors of students’ conceptual knowledge of the names of the planets in our solar system. A similar, non-significant finding was shown when negative emotions at pretest were used as predictors of students’ knowledge of the planet’s names at pretest.

Concept Item 3 was a dichotomous variable. The item asked students whether Pluto should still be a planet. Students who gave a Yes response were given a 0 (non-scientific), and students who stated No were given a 1 (scientific). I conducted logistic analyses to investigate whether emotions at pretest were predictors of students’ responses at pretest. The model using students’ responses to Concept Item 3 as the dependent variable and positive emotions at pretest as the predictor variable was significant. The analysis showed that positive emotions at pretest are significant predictors of students’ Yes responses to Concept Item 3 at pretest (\( B = 1.28 \), Wald = 3.76, \( df = 1 \), SD = .382, \( p = .360, B = .967 \)).
.05). To interpret Beta, I ran an analysis of the odd ratio. The findings of this analysis showed an odd ratio of 3.60 which suggests a 260% increase in students’ responses to reflect the scientific viewpoint for Concept Item 3 given a one unit increase in students’ positive emotions at pretest.

I used the same logistic regression strategy to examine whether negative emotions at pretest significantly predicted students’ responses to Concept Item 3 at pretest. The analysis failed to show negative emotions at pretest as predictors of students’ responses at pretest, (omnibus chi-square = 1.957, df = 1, p = .162).

I used the ordinal regression strategy to examine whether emotions at pretest were predictors of Concept Item 4 (Write an explanation for your answer to “Should Pluto still be a planet?”) at pretest. The findings of this analysis are shown in Table 14. The model using students’ responses to Concept Item 4 as the dependent variable and positive emotions at pretest as the predictor variable was significant (B = .903, Wald = 3.92, df = 15, p = .034). A similar strategy was used to test whether negative emotions at pretest were significant predictors of students’ responses at pretest. Negative emotions again failed to make a contribution to the prediction equation.

Emotions at pretest failed to be significant predictors of Concept Item 5 at pretest (“Why do scientists no longer call Pluto a planet?”). The results of this series of ordinal regression analyses are summarized in Table 14. The findings show that positive emotions at pretest were not significant predictors of students’ conceptions about Pluto’s reclassification at pretest. Negative emotions at pretest also failed to be significant predictors of students’ concepts about why Pluto is no longer classified as a planet at pretest.
The ordinal regression strategy was also used to see if emotions at pretest were significant predictors of Concept Item 6 ("Why did scientists change the definition of planet?") at pretest. These findings are summarized in Table 14. Positive emotions again failed to contribute significantly to the variance for Concept Item 6. The analyses revealed a similar finding for negative emotions at pretest, showing that they were not significant predictors of students' conceptions of why the definition of planet was changed.

*Emotions Predicting Change*

A second series of linear regressions was conducted to examine whether emotions at posttest were predictors of change in students: NOS beliefs, attitudes about Pluto's reclassification, and their conceptions about the planets and Pluto from pretest to posttest. Emotions must be measured in the moment (Linnenbrink, 2006). Therefore, emotions at posttest were those most closely associated with students' responses on these surveys at posttest so I used them as the predictor variables for this series of analyses.

I calculated the change score variables for the NOS beliefs measure and the APR measure by subtracting the mean scores of that specific measure at pretest from the mean scores of that same measure at posttest. For example, to calculate the change score variable for students' NOS beliefs, I subtracted the pretest mean score from the posttest mean score. This process was repeated for calculating the APR change score variable. The change score variables for the individual concept items were calculated by subtracting the raw score at pretest from the raw score at posttest.

I conducted a series of linear regression analyses to determine whether emotions at posttest were predictive of change in students' NOS beliefs from pretest to posttest. I
used emotions at posttest as the predictor variables and the change score variable on students’ NOS beliefs as the dependent variable. Table 12 summarizes the results. Results of the regression analyses revealed no significant predictive relationships. That is, positive emotions and negative emotions each failed to predict change in students’ NOS beliefs from pretest to posttest.

A similar regression strategy was used to determine whether students’ emotions at posttest were predictive of attitude change from pretest to posttest. The means for students’ attitudes reflect a forward shift towards acceptance from pretest (M = 2.5) to posttest (M = 2.9). I conducted a t-test to compare the differences between these two means. The analysis showed a significant difference between students’ attitudes at pretest and their attitudes at posttest, t(17.83), df = 50, p = .000. Table 12 summarizes the results of the linear regressions between emotions at posttest and attitude change from pretest to posttest. Positive emotions at posttest account for a significant 10.6% of the variance in attitude change from pretest to posttest, [F(1, 46) = 6.58, p = .014, Adjusted R² = .106, B = .438]. The analyses further revealed that negative emotions at posttest accounted for a significant portion of the variance in students’ attitude change from pretest to posttest, [F(1, 45) = 8.03, p = .007, Adjusted R² = .133, B = -.442]. It may be likely that negative emotions were fostering critical thinking and deep engagement with the information presented in the refutation text, thus increasing the likelihood of change from pretest to posttest.

I conducted a series of linear regressions to determine whether emotions at posttest were significant predictors of change from pretest to posttest on Concept Item 1. Table 13 summarizes the results. Positive emotions at posttest were not significant
predictors of change in students’ concepts about the number of planets in the solar system from pretest to posttest. Negative emotions also failed to significantly predict change in students’ responses to Concept Item 1 from pretest to posttest.

The linear regression analyses indicated that positive emotions at posttest were significant predictors of change in students’ responses from pretest to posttest on Concept Item 2. Positive emotions accounted for 9.5% of the variance in the change in students’ responses from pretest to posttest \[F(1, 45) = 5.81, p = .020, \text{ adjusted } R^2 = .095, B = -.659\]. Negative emotions at posttest failed to be predictive of change in students’ knowledge of the names of the planets from pretest to posttest. The results of these analyses are summarized in Table 13.

I conducted a logistic regression analysis using positive emotions at pretest as the predictor variable and the change in Concept Item 3 from pretest to posttest as the dependent variable. This analysis was unsuccessful because the dependent variable had more than 2 missing cases. I then ran the McNemar chi-square test for matched pairs to measure the change in students’ responses from pretest to posttest on Concept 3. The findings show there was a significant change from pretest to posttest, 16 students changed from Yes to No (posttest), 2 from No to Yes (posttest). The results also indicated that 30 students remained constant in their responses from pretest to posttest (24 Yes, 6 No).

Next, I conducted linear regressions to examine whether positive emotions at posttest predicted change in students’ responses to Concept Item 3 from pretest to posttest. Table 13 summarizes the findings. Positive emotions were significant predictors of change in students’ responses from pretest to posttest on Concept Item 3 \[F(1, 46) = 6.30, p = .016, \text{ adjusted } R^2 = .101, B = .255\]. Negative emotions at posttest were
significant predictors of change in students' responses to whether Pluto should remain a planet, \[ F(1, 45) = 9.99, p = .003, \text{ adjusted } R^2 = .163, B = -.277 \].

The series of ordinal regression analyses using emotions at posttest to predict change in Concept Item 4 from pretest to posttest showed no significant associations. These findings are summarized in Table 14. Positive and negative emotions at posttest each failed to account significantly for any of the variance in the change from pretest to posttest in students' scientific knowledge about why Pluto should or should not remain a planet.

The ordinal regression strategy was applied using the change variable for Concept Item 5 as the dependent variable in the prediction equation. Positive emotions at posttest failed to predict change in students' concepts about Pluto's reclassification from pretest to posttest. Similarly, the findings also showed that negative emotions reported at posttest did not significantly predict change in students' responses from pretest to posttest on Concept Item 5. Table 14 summarizes these findings.

This trend continued when the change variable on Concept Item 6 was used as the dependent variable in the prediction equation. The findings are presented in Table 14. Positive emotions at posttest again failed to predict change in students' conceptual knowledge from pretest to posttest. The findings were similar for negative emotions at posttest failing to be significant predictors of change from pretest to posttest on students' knowledge about why scientists changed the definition of planet.

*Negative Emotions Related to Absolute Value of Change*

Research Question 2 also asked, "Are negative emotions associated with greater entrenchment or greater change toward the accepted scientific view, or will it differ for
different students?" I created absolute change variables using the NOS beliefs mean difference score from pretest to posttest as well as the APR mean difference score from pretest to posttest. I also created absolute change variables using each of the individual items from the Concepts instrument, calculating the absolute difference of the raw scores from pretest to posttest on each item. The means and standard deviations for each of the absolute change variables are presented in Table 15.

Correlations. I used the Pearson product-mean correlation to explore the relationship between negative emotions at posttest and the absolute value of change in students' NOS beliefs from pretest to posttest. Negative emotions at posttest failed to show a significant relationship with the change to students' NOS beliefs from pretest to posttest, \( p = .810 \).

A second Pearson product-mean correlational analysis examined whether a significant relationship existed between negative emotions at posttest and the absolute value of change in students' attitudes from pretest to posttest. The correlation was not significant, \( p = .278 \).

The correlational analysis between negative emotions at posttest and the absolute change value from pretest to posttest for Concept Item 1 ("How many planets are in our solar system?") was not statistically significant, \( p = .377 \). The correlations were not significant between negative emotions at posttest and the absolute change value in Concept Item 2 pretest to posttest ("List the planets in our solar system"), \( p = .064 \).

I ran Spearman rho correlations when using the absolute change variables for Concept Items 3, 4, 5, and 6 because these items were rank ordered using the rubric as previously described. The correlations between negative emotions at posttest and the
absolute change value with Concept Item 3 ("Should Pluto still be a planet?") showed a small, significant relationship, \((r_s = -0.294, p = 0.045, n = 47)\). I also ran the frequency counts to determine the number of Yes responses at pretest \((n = 43)\) and posttest \((n = 28)\), as well as the number of No responses at pretest \((n = 9)\) and posttest \((n = 23)\). The frequencies show a shift in students' responses from pretest to posttest towards acceptance of Pluto as a dwarf planet. These findings suggest that negative emotions are related to the absolute value of change in students' responses to Concept Item 3.

Negative emotions at posttest were not significantly correlated with the absolute value of change in students' responses from pretest to posttest on Concept Item 4 ("Explain your answer to question #3), \(p = .300\). The Spearman rho correlation between negative emotions at posttest and the absolute value of change from pretest to posttest in students' responses to Concept Item 5 ("Why do scientists no longer call Pluto a planet?") was not significant, \(p = .828\). Similarly, the correlation between negative emotions at posttest and the absolute change in students' responses to Concept Item 6 ("Why did scientists change the definition of planet?") was not significant, \(p = .201\).

Regressions. I conducted a linear regression analysis to examine the role of negative emotions at posttest as a predictor of the absolute value of change in students' NOS beliefs from pretest to posttest. The results are shown in Table 16. The analysis showed that negative emotions at posttest were not significant predictors of the absolute value of change in students' NOS beliefs from pretest to posttest, \(p = .810\).

The regression strategy was also used to determine if the absolute value of change in students' attitudes from pretest to posttest could be predicted by negative emotions at
posttest. Results are summarized in Table 16. Negative emotions failed to predict change in students’ attitudes from pretest to posttest, $p = .278$.

I conducted a series of linear regressions on Concept Items 1, 2, 4, 5, and 6. Negative emotions at posttest were the predictor variable. The absolute value of change variable for each Concept Item was used as the dependent variable. Table 16 displays the results. The series of regression analyses showed that negative emotions are not significant predictors of the absolute value of change in student’s scientific knowledge about planets.

I conducted a logistic regression analysis using negative emotions at posttest to predict change in student’s responses to Concept Item 3 from pretest to posttest. The analysis revealed a significant finding (omnibus chi-square = 3.92, $df = 1, p = .048$). However, the findings showed that negative emotions at posttest were not significant predictors of the absolute value of change in students’ responses to Concept Item 3 from pretest to posttest.

**Summary**

The analyses showed that positive and negative emotions were present when students were learning about the reclassification of Pluto. In general, students reported experiencing more negative than positive emotions, and those negative emotions were more intense than the positive emotions.

**Correlations**

The analyses failed to reveal significant associations between emotions and students’ NOS beliefs. However, the correlational analyses between emotions at pretest
and attitudes at pretest suggest that positive emotions are positively correlated with acceptance of the reclassification. In contrast, negative emotions were inversely correlated with acceptance, suggesting that students who were mad were less likely to accept the change to Pluto’s status.

In addition, the correlation analyses showed a significant association between emotions at posttest and Concept Item 3 at posttest. Positive emotions were correlated with acceptance of Pluto as a dwarf planet while negative emotions were associated with attitudes of disagreement to the reclassification. It is important to note that positive and negative emotions at pretest were not correlated with Concept Item 3 at pretest. This difference in the correlations may be due to students experiencing stronger emotions at posttest as the result of reading the text than they reported at pretest.

Positive emotions at pretest were also significantly correlated with Concept Item 4 which asked students to provide a rationale for their response to Item 3. The analyses failed to show significant associations between positive and negative emotions and the remaining Concept Items at pretest and posttest.

Regressions

The analyses revealed no significant predictive relationships between emotions – positive and negative – and students’ NOS beliefs at pretest. In addition, emotions were not predictive of NOS belief change from pretest to posttest. However, the analyses showed that positive emotions at pretest were predictive of students’ attitudes of acceptance of Pluto’s reclassification at pretest. Negative emotions at pretest were also found to be significant predictors of students’ attitudes of non-acceptance towards Pluto’s reclassification at pretest. In addition, both positive and negative emotions at posttest
were found to be significant predictors of change in students' attitudes from pretest to posttest.

Further, the regression analyses revealed a significant relation between positive emotions at posttest predicting change in students' responses to Concept Item 2 from pretest to posttest. This finding suggests that students who reported positive emotions were likely to correctly name the planets, omitting Pluto from their responses from pretest to posttest.

The regression analyses showed that positive emotions at pretest were significant predictors of students' responses to Concept Item 3 at pretest; however, negative emotions were not. The analyses also indicated that positive and negative emotions at posttest were predictive of change in students' responses from pretest to posttest. It may be the case that both positive and negative emotions fostered deep engagement with the ideas in the text thus increasing the likelihood of conceptual change on this item.

Positive emotions at pretest were also shown to be significant predictors of students' responses to Concept Item 4 at pretest. However, the regression analyses failed to reveal negative emotions at pretest as predictors of students' answers to Item 4 at pretest. In addition, the regression analyses failed to show emotions as predictors of change from pretest to posttest on Concept Item 4.

The regression analyses also failed to show emotions at pretest as significant predictors on Concept Items 1, 2, 5, and 6 at pretest. This pattern was repeated when emotions were used as predictors of change to Concept Items 1, 2, 5, and 6 from pretest to posttest.
Absolute change value variable

The correlation analyses failed to show significant relationships between negative emotions at posttest and the absolute value of change in students’ NOS beliefs, attitudes, and Concept Items 1, 2, 4, 5, and 6. A significant association was revealed between negative emotions at posttest and change in students’ responses to Concept Item 3. A similar pattern was shown when negative emotions were used as the predictor variable. However, negative emotions at posttest failed to predict the absolute value of change in students’ NOS beliefs, attitudes, and each of the Concept items from pretest to posttest.

Increasing Engagement to Promote Change

My third research question asked: Does enhancing the reading of a refutational text through small group discussions promote greater change than rereading alone in students’ a) beliefs, b) attitudes, and c) conceptual knowledge about planets? I conducted separate repeated measures mixed design ANOVAs using condition (rereading plus discussion, rereading only) as the between subjects variable and time of test (Time 1, Time 2, Time 3) as the within subjects variable. Each of the ANOVAs examined the outcome measures: NOS beliefs, attitudes, and conceptual knowledge. Two separate ANOVAs were conducted on each construct to examine change: a) from pretest to posttest, b) from pretest to delayed posttest.

Beliefs about the Nature of Science

A repeated measures ANOVA was conducted to compare scores on the Beliefs about the Nature of Science measure using condition group (discussion plus reread, reread only) as a between group factor and time of test (Time 1 – pretest, Time 2 –
posttest) as the within subjects factor. The means and standard deviations are presented in Table 17. Results showed no advantage for the discussion plus rereading group over the reread only group. However, the analysis did reveal significant gains in students’ NOS beliefs from pretest to posttest in both conditions \([F(1, 42) = 11.254, p < .05]\). This main effect of time is shown in Figure 1. The results failed to show an interaction between condition groups and learning over time, suggesting that NOS beliefs increased through rereading and rereading plus discussions.

A second repeated measures ANOVA was conducted to compare scores on the NOS Beliefs measure using condition group (discussion plus reread, reread only) as the between group factor and time of test (Time 1 – pretest, Time 3 – delayed posttest) as the within subjects factor. The means and standard deviations for NOS beliefs are shown in Table 17. There was no significant effect of condition group. However, there was a significant main effect of learning over time indicating that gains in nature of science beliefs occurred through both groups \([F(1, 48) = 16.484, p = .000]\). Results also revealed that no significant interaction between rereading conditions and learning over time indicating that learning occurred through both rereading conditions.

**Attitudes about Pluto’s Reclassification**

A repeated measures ANOVA was conducted to compare attitudes towards Pluto’s dwarf classification again using rereading condition (rereading, rereading plus discussion) as the between subjects factor and scores on the Attitudes about Pluto’s Reclassification measure at Time 1 and Time 2 as the within subjects factor. The means and standard deviations of students’ attitudes towards the reclassification are presented in Table 17. The results showed no significant differences between rereading conditions. A
significant main effect of change in attitudes over time was found indicating that
students' attitudes shifted towards greater acceptance of Pluto's reclassification \[F(1, 46) = 7.694, p < .01\]. The main effect of time on attitude change is shown in Figure 2.

I conducted a second repeated measures ANOVA to compare students' attitudes about the reclassification of Pluto using rereading groups (rereading, rereading plus discussion) as the between subjects factor and scores on the attitudes measure at pretest and delayed posttest as the within-subjects factor. The means and standard deviations are shown in Table 17. Again, the results showed no significant advantage for the reread plus discussion group over the reread only group. A significant main effect was revealed in students' attitudes from pretest to delayed posttest \[F(1, 47) = 14.711, p = .000\]. There were no significant interactions.

*Concepts about Planets*

A similar ANOVA strategy was used for analyzing each of the Concept items. A repeated measures ANOVA was conducted to compare students' concepts about the number of planets in our solar system using rereading groups (rereading, rereading plus discussion) as the between subjects factor and scores on Concept Item 1 at pretest and posttest as the within-subjects factor. Table 18 displays the means and standard deviations. The analysis showed no significant differences between rereading groups. In addition, no significant effect for time was found, indicating that students' concepts about the number of planets in the solar system remained fairly stable from pretest to posttest. No significant interactions were shown.

I conducted a second repeated measures ANOVA to compare students' scientific knowledge about the number of planets in our solar system using rereading groups as the
between subjects factor and scores on Concept Item 1 at pretest and delayed posttest as the within subjects factor. A similar trend was shown with this set of findings. The means and standard deviations are presented in Table 18. The ANOVA failed to show a significant main effect of time. There were also no significant differences between rereading groups from pretest to delayed posttest on student’s concepts about the number of planets. The analysis showed no significant interaction.

The repeated measures ANOVA strategy was used to compare scores on Concept Item 2 using rereading group as the between group factor and time of test (pretest, posttest) as the within subjects factor. The means and standard deviations are presented in Table 18. The results found no significant differences between the reading groups. The findings also failed to show a main effect of time. This suggests that students’ ability to correctly write down the names of the planets remained fairly stable over time. In addition, no significant interaction was shown.

I then conducted a second repeated measures ANOVA to compare students’ scores on Concept Item 2 using rereading group as the between group factor and time of test (pretest, delayed posttest) as the within subjects factor. Table 18 displays the means and standard deviations. A similar pattern was shown for this set of analyses in that there was no significant main effect of condition nor was there a significant main effect of time. The analysis also failed to show a significant interaction.

The repeated measures ANOVA strategy was used to analyze Concept Item 3. Rereading group was used as the between group factor and time of test (pretest, posttest) as the within subjects factor. The means and standard deviations are displayed in Table 20. The analysis did not reveal a main effect of condition, indicating no significant
advantage between rereading groups. However, the analysis did show a significant main
effect of time on Concept Item 3, \( F(1, 46) = 13.527, p = .001 \). This main effect of time
is reflected in the increase of the means from pretest to posttest as shown in Table 19.
Students in both groups experienced a forward shift in their acceptance towards Pluto’s
reclassification. The results failed to show a significant interaction.

The second repeated measures ANOVA conducted on Concept Item 3 used
rereading group as the between group factor and time (pretest, delayed posttest) as the
within subjects factor. Table 19 shows the means and standard deviations. No significant
differences were found between groups. A main effect of time was shown, indicating a
significant shift in students’ acceptance of Pluto’s change, \( F(1, 48) = 17.959, p = .000 \).
This suggests that the forward shift towards acceptance experienced from pretest to
posttest was sustained over time through delayed posttest. No significant interaction was
found.

To analyze students’ responses to Concept Item 4, I conducted the repeated
measures ANOVA using rereading group as the between group factor and time (pretest,
posttest) as the within subjects factor. The means and standard deviations are shown in
Table 19. The analysis failed to show a main effect of group, indicating that both groups
performed similarly. A main effect of time was revealed indicating that students’
rationale for why Pluto should (or should not) remain a planet incorporated more
scientific reasons from pretest to posttest, \( F(1, 46) = 14.825, p = .000 \). No significant
interactions were found.

The repeated measures ANOVA comparing students’ responses to Concept Item 4
using rereading group as the between subjects factor and time (pretest, delayed posttest)
showed a similar trend. Table 19 displays the means and standard deviations. Again, there was no main effect of group from pretest to delayed posttest. However, a main effect of time was found from pretest to delayed posttest, \( F(1, 48) = 10.910, p = .002 \). This finding suggests that students' concepts about why Pluto should remain a planet included more scientific reasons at delayed posttest than at pretest. The analysis did not reveal any significant interactions.

I also conducted the repeated measures ANOVA to compare students' responses to Concept Item 5 using rereading group as the between subjects factor and time (pretest, posttest) as the within subjects factor. Table 20 presents the means and standard deviations. As with the previous Concept item analyses, this analysis on Concept Item 5 found no significant differences between groups. A main effect of time was revealed, \( F(1, 46) = 7.453, p = .009 \). This indicates that students' responses incorporated more correct scientific concepts to this item from pretest to posttest. No significant interactions were found.

A second repeated measures ANOVA was conducted to compare students' answers on Concept Item 5 using rereading group as the between subjects factor and time (pretest, delayed posttest) as the within subjects factor. The means and standard deviations are displayed in Table 20. Again, the analysis failed to show a significant main effect of condition. The analysis also showed that there was no main effect of time. As shown in the means students' conceptions about why scientists no longer call Pluto a planet were relatively the same at pretest and delayed posttest. This finding is common in conceptual change research in that individuals often experience a backward shift towards their previously held misconceptions from posttest to delayed posttest.
The repeated measures ANOVA strategy was used to compare students’ responses to Concept Item 6 using rereading group as the between subjects factor and time (pretest, posttest) as the within subjects factor. The means and standard deviations are presented in Table 20. The analysis showed no significant advantage between rereading groups. A main effect of time was found from pretest to posttest, \( [F(1, 46) = 69.785, p = .000] \). This main effect indicates that students experienced conceptual change from pretest to posttest in their understanding of why scientists changed the definition of planet. No significant interaction was found.

I conducted the repeated measures ANOVA for Concept Item 6 using rereading group as the between subjects factor and time (pretest, delayed posttest) as the within subjects factor. Table 20 shows the means and standard deviations. The analysis revealed a main effect of group from pretest to delayed posttest, \( [F(1, 48) = 6.789, p = .012] \). Figure 3 makes this main effect more visible. These findings indicate a significant advantage for the reread plus discussion group. In addition, the analysis showed a main effect of time from pretest to delayed posttest \( [F(1, 48) = 64.190, p = .000] \) (see Figure 3). Students’ conceptual change about why scientists change the definition of planet was sustained over time. No significant interaction was revealed.

I conducted a post hoc repeated measures ANOVA using rereading group as the between subjects factor and time (posttest, delayed posttest) as the within subjects factor to determine whether the discussion format helped to maintain the learning effect. No significant main effect of group or time was found. A significant interaction was revealed \( (p = .05) \) indicating that the effect was maintained.
Qualitative Analyses

I conducted a content analysis of the individual student interview transcripts. Students’ responses were coded into three general categories based on the constructs highlighted in this study. The general categories were Emotions, Attitudes, and Nature of Science Beliefs. Within each category, I coded subcategories. Emotions were grouped according to valence, positive and negative. Attitudes were categorized according to agree or disagree. Table 21 shows the categories and sub-categories for Emotions and Attitudes by participant. Student’s NOS beliefs were grouped into Certainty of Knowledge or Development of Knowledge categories. These NOS Beliefs categories and sub-categories are shown in Table 22.

Emotions

Students experienced a range of emotions in relation to the reclassification of Pluto to a dwarf planet. Positive emotions were reported by only one student, Tyler. Tyler said that he felt positive emotions such as fine and happy after he had read the refutation text about Pluto’s reclassification. He stated, “I’m fine about it. I’m pretty happy.”

Tyler also reported feeling surprised when he first heard about Pluto being a dwarf planet. The correlational analyses reported previously clustered surprised with negative emotions. However, Tyler’s response suggests that his surprised response was perhaps more neutral than negative. He stated,

Pretty surprised because everyone used to think that was a really small planet. And I thought it was always a planet, too. And I didn’t learn until the year after and everyone was arguing about it, so I was pretty surprised (Interview, 11/21/07).
Two additional students reported being surprised about Pluto’s dwarf status. Anna and Aaron reported being surprised when they first heard about the reclassification because Pluto had been a planet for a very long time. Aaron continued to feel surprised after reading the text, stating, “I’m still surprised because I don’t know, they might change it back.” The remaining emotions expressed by Anna and Aaron were negative. This finding suggests that surprise may be correlated with negative emotions in this context.

Three out of the four students interviewed reported experiencing negative emotions in relation to Pluto’s dwarf status. Jaime and Aaron stated that they felt sad because they wanted Pluto to remain a planet. Jaime explained, “I felt kind of sad because I wanted it to be a planet.” However, after reading the refutation text, Jaime reported feeling less sad. Aaron, too, experienced sadness, stating, “I kind of felt a little sad because they reported it, they said that it was a planet but now they figured out that it’s not a planet because of the Kuiper Belt.”

The three students who reported feeling negative emotions related those emotions to the fact that Pluto had always been a planet. Jaime stated, “I was mad and frustrated... I just thought it would be a planet because my whole life I knew it as being a planet. And now that it’s not, it just doesn’t seem the same!” In addition, Anna and Aaron reported feeling surprised about the reclassification because Pluto had always been a planet.

Nature of Science Beliefs

Certainty of Knowledge. Three of the four students interviewed held the belief that science knowledge changes. Tyler, Jaime, and Aaron each expressed the belief that science knowledge changes based on new evidence. For example, Tyler explained that science knowledge changes as scientists use experimentation and evidence to disprove
hypotheses. Jaime explained that science knowledge changes as scientists “try different experiments and they compare it... to see whatever fits and what the answer comes up to.” Aaron believed that science knowledge changes with the discovery of new information.

In contrast, Anna’s NOS beliefs suggest that science knowledge should not change if it is something that we have known for a long time. She stated, “It’s been a planet for a long time, so why not just keep it a planet.” This suggests that Anna believes canonical science knowledge should not change.

Each of the four students interviewed held the NOS belief that scientists can disagree and debate with one another. Tyler and Anna each expressed the view that scientists can debate among themselves over a topic until important evidence is discovered. Once the important evidence is discovered, scientists will come to agreement. Tyler explained, “I don’t think they will [come to an agreement] until they find something really, really big about it.” Similarly Anna stated,

If one person has another reason and then the other person has another explanation, then they could find more stuff out and even try to go more beyond what they know to get other stuff so they could agree on something (Interview, 11/21/07).

These findings suggest that these students view the role of debate as facilitating change in science knowledge when scientists are able to come to a consensus.

In contrast, Jaime and Aaron see the outcome of scientific debate as most often inconclusive. Jaime explained,
Some scientists disagree and others agree. And then they kind of work things out. And they go over the experiments again. And I don’t think they always come to a final answer. I think there’s always different answers no matter when sometimes they just don’t agree after they go over it (Interview, 11/21/07).

Aaron expressed a similar view when he explained that some scientists still think of Pluto as a planet while others think of it as a dwarf planet. He stated, “They don’t always agree with each other.” These findings suggest that Jaime and Aaron believe that scientists are continually debating evidence without coming to a final consensus.

The content analysis revealed a pattern in the students’ beliefs about the role of new discoveries in changing scientific knowledge. Three out of the four students interviewed acknowledged that what we know in science can change based on new discoveries. Tyler and Anna hold the belief that scientists will always discover new information which will result in changing scientific knowledge. Tyler connected this view to the change in the definition of planet, stating, “They thought about it and then they changed the definition because they didn’t want too many planets.” Aaron also related the role of new discoveries in changing science knowledge with the discovery of the Kuiper Belt. These findings indicate that the students understood that science knowledge can change when new discoveries are made. In addition, the analysis suggests that students were able to contextualize their NOS beliefs in relation to the discovery of the Kuiper Belt and the subsequent change to the definition of planet.

Development of Knowledge. The content analysis revealed a distinct pattern in the students NOS beliefs regarding the use of evidence in the development of scientific
knowledge. All four students expressed their beliefs that scientists use evidence to make
decisions. Tyler explained, “They do experiments and they have hypotheses and then
they try to disprove them. And then they’ll look for stuff that has relation to them.” In
Tyler’s view, evidence is used to disprove hypotheses. Anna explained that scientists use
evidence to make decisions that inform scientific knowledge. Aaron also understands the
use of evidence in science knowledge, and he emphasized the notion that scientists must
have a lot of information in order for the knowledge to be sound. He stated,

I think they should study it a little more because they just discovered the [Kuiper
Belt] 27 years ago. I think they should just study it a little more...I think they
should get some more research and study it a little more before they make a final
decision (Interview, 11/21/07).

This suggests that Aaron understands how new discoveries can shape scientific
knowledge but that he expects the information from the discoveries to be deeply
investigated.

Jaime and Aaron each discussed the use of evidence and opinions in the
development of science knowledge. Jaime explained that scientists use both evidence and
opinions, but that they tend to rely more on evidence than opinions in making decisions.
Aaron believes that a balance exists between the use of evidence and opinions. He stated,
“I would say there’s a balance because if they always agreed with each other, the world
would be kind of dull because they don’t always have a different opinion.” This suggests
that the students understand both the empirical and creative components of the nature of
science.
Componential Analysis

I conducted a second level of analysis on the student interview transcripts. This analysis was a componential analysis that allowed me to look at the attributes of each category in relation to each other (Spradley, 1979). The componential analysis shows the patterns within the individual constructs by student as well as the relationships that may exist between the constructs. The results of the componential analysis are shown in Table 23.

The componential analysis revealed a pattern between the students’ overall degree of change, their emotions, NOS beliefs, and attitudes. For example, Tyler experienced a low degree of change in his NOS beliefs, attitudes towards Pluto’s change, and conceptual knowledge of the planets. It is important to note that even though Tyler’s responses reflected a low degree of change this low change was likely due to him already holding constructivist NOS beliefs, attitudes of acceptance towards Pluto’s reclassification, and primarily scientific knowledge about the planets. The componential analysis shows that Tyler held positive emotions in relation to the reclassification and that he agreed with the scientist’s decision to change Pluto to a dwarf planet. An examination of the frequency of Tyler’s NOS beliefs responses taken all together suggests his understanding of the certainty of science knowledge is based on the use of debate, evidence, new discoveries, and the view that science knowledge changes.

The componential analysis indicated that Anna, who experienced an overall high level of change from pretest to posttest, reported experiencing negative emotions and that she disagreed with the scientists’ decision to reclassify Pluto. The analysis suggests that she understands that science knowledge changes with new discoveries, evidence, and the

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use of scientific debate. However, she disagrees with the scientists’ decision to reclassify Pluto even though she holds these constructivist NOS beliefs.

Jaime, who experienced a low level of overall change in NOS beliefs, attitudes, and conceptual knowledge from pretest to posttest, also reported negative emotions and a general disagreement with Pluto’s reclassification. The componential analysis suggests that Jaime holds constructivist NOS beliefs because she understands that scientific knowledge is based on the use of evidence, opinions, debate, and as well as the view that science knowledge changes. The findings also suggest that negative emotions may be associated with the general disagreement towards Pluto’s change. The overall trend seems to suggest that even though Jaime holds constructivist NOS beliefs, those beliefs may not be sufficient to influence change in Jaime’s attitudes towards acceptance of Pluto’s reclassification.

The overall pattern for Aaron suggests that he experienced both positive and negative emotions and was uncertain about his attitudes towards Pluto’s reclassification. Aaron experienced an overall high level of change from pretest to posttest on the Beliefs, Attitudes, and Concepts surveys. The componential analysis suggests that Aaron holds constructivist NOS views when taking all of his responses together. It is likely that he understands the changing nature of science knowledge, the use of debate, evidence, opinions, and new discoveries in shaping what we know in science.

Taken all together, the componential analyses suggest these students’ understanding of the certainty of science knowledge is based on the use of debate, evidence, new discoveries, and the view that science knowledge changes. The overall trend seems to suggest that negative emotions may be acting to override students’
constructivist NOS beliefs and thereby influencing their resistance towards Pluto’s reclassification.

**Attitudes**

The content analysis revealed that one student agreed with the scientists’ decision to reclassify Pluto to a dwarf planet. Tyler agreed with the decision after reading the refutation text because Pluto does not fit the new definition of planet. He explained, “I felt fine about it after I read it because how they changed the definition. Well, if the definition changed then it should no longer be a planet.”

Three out of the four students interviewed disagreed with the decision to change Pluto’s status. Two students, Anna and Jaime, explained that they disagreed with the scientists’ decision because Pluto had been a planet for a long time. Anna continued to disagree with the change to Pluto “because it’s so small and cute!”

After reading the refutation text, however, Jaime’s attitude shifted slightly towards acceptance. She said, “I just wish it was still kind of a planet but I’m okay with it.” Jaime’s uncertainty with the decision was also evidenced when she shifted back towards disagreeing with the decision. When asked if she could participate in the scientists’ decision making process Jaime explained, “I would probably keep it as a planet because it’s more difficult to take it off because there are a lot of other dwarf planets. So it’s just easier to keep it on the list.” This finding suggests that Jaime’s initial attitudes against the decision to change Pluto’s status may be shifting towards acceptance after reading the refutation text.

A similar trend of uncertainty towards Pluto’s reclassification was found in Aaron’s responses. Aaron reported a sense of agreement with the scientists’ decision to
change Pluto to a dwarf planet after he had read the text. He explained, “After I read the papers, I would have to say I would vote it as a dwarf planet because the size, shape, and orbit.” However, when asked if Pluto should still be a planet he stated,

I think they should do some more research on the Kuiper Belt because they’ve been studying the Belt for a long time and all the other types of planets. So I think they should study it a little more because they just discovered that 27 years ago (Interview, 11/21/07).

Aaron’s responses suggest that he does not completely agree with the reclassification to Pluto, but his views are perhaps closer to acceptance of the decision than rejection.

Small Group Discussions

I purposefully selected Discussion Group 1 for analysis. This decision was based on the richness of students’ responses during the discussion in comparison to the students’ responses in each of the remaining small groups. I conducted a content analysis on the transcript from the small group discussion, coding students’ responses by the three constructs explored in this study, emotions, NOS beliefs, and attitudes. I did not code the transcripts for conceptual knowledge because students’ concepts about planets, Pluto, and the definition change to planets were included on the Concept survey. Students’ responses to those items were scored using a rubric as previously described.

Emotions

The content analysis revealed only one student response that included an emotional reference. During the discussion segment that focused on students’ reactions to Pluto no longer being a planet, Jaime stated, “And Pluto is my favorite planet besides
Earth. So I've always liked it to be a planet. And once they declared it not a planet, I
freaked out!" The lack of emotional references made by students throughout the
discussion may be the result of the content of the questions posed. The questions were
specifically related to the nature of science, the discovery of the Kuiper Belt, and Pluto's
reclassification. The questions did not focus on students' emotions to these key ideas.

*Nature of Science Beliefs*

I conducted a litany analysis, a form of discourse analysis, on the students' responses related to their NOS beliefs. The richness of the students' responses in relation to the nature of science warranted a different type of analysis than content analysis. The litany analysis provided an avenue for looking at the latent, underlying ideas in discourse (Santa Barbara Classroom Discourse Group, 1994). The analysis includes five categories: Who, Can do or say, What, Under what conditions, For what purposes, and Outcomes or consequences. Table 24 and Table 25 show the results of the litany analysis of students NOS beliefs during the small group discussion.

The analysis revealed a general pattern among students' beliefs about scientists. Taken together, the findings suggest that these students believe that scientists make
mistakes, disagree with one another, and engage in debate. Students' responses suggest
that a likely outcome from these disagreements and debates is that scientists will change
what we know in science. The findings also suggest that when scientists discover those
mistakes they change scientific knowledge. It is likely that students believe that when
scientists say something is correct it has the potential to be proven wrong. A potential
outcome for scientists changing their minds is that it can cause confusion. The analysis
suggests that it may be likely that students are resisting accepting Pluto as a dwarf planet because they perceive scientists as fallible and uncertain in their knowledge claims.

In addition, the litany suggests that students understand the rationale for the new definition of planet but the consequences of this change is disconcerting to them. It may be the case that students are continuing to view Pluto as a planet because the conditions are that Pluto has always been a planet to them. The analysis suggests that students understand that the definition was based on evidence, the discovery of the Kuiper Belt, but this evidence is not sufficient for them to change their classification of Pluto. It is likely that accepting Pluto as a dwarf planet would be disconcerting to these students because they perceive scientists as fallible.

The litany analysis also suggests that these students hold the view that people can rely on their religious beliefs when they are unsure about something in science. It may also be the case that the students believe that people should retain their beliefs when science knowledge contradicts those beliefs. The consequence for changing one’s beliefs is that it will “mess up your mind.”

**Attitudes**

I conducted a content analysis of students’ responses given during the small group discussion to examine their attitudes towards the reclassification of Pluto. The findings are displayed in Table 26 and Table 27. I coded students responses into the category of attitude and then into the subcategories of agree and disagree. In general, students tended to disagree with Pluto’s dwarf status. Six of the seven students in this group disagreed with the reclassification.
A trend in students' disagreement with the reclassification was found in relation to Pluto's traits as a planet. Four students explained that scientists should not reclassify Pluto based on Pluto crossing over into Neptune's orbit. For example, Josh explained, I think they shouldn't downsize Pluto because even though it crosses into Neptune's orbit it has two of the three. I think that even though it crosses, I just think it should be. Because if it just crosses at one or two spots I think that's okay. Because the only problem would be if it collided. But I don't think that will ever happen (Discussion, 11/15/07).

The students' responses suggest that they did not find the argument of Pluto crossing into Neptune's orbit an adequate justification for the reclassification.

The content analysis revealed a second trend in students' disagreement with Pluto's dwarf status. Two students disagreed with the scientist's decision because they had always known Pluto as a planet. Jim wanted Pluto to remain a planet because "we would have nine, how it always was." Similarly, Jaime stated, "I wouldn't really know what to say except for the fact that I have grown up with Pluto being a planet. I'm just used to having nine planets. We've all grown up with Pluto being a planet."

Additional comments suggesting students' disagreement with Pluto's reclassification included the view that scientists can sometime be wrong and that people may live on Pluto someday. Jim resisted accepting the change even though he understood that the definition was changed based on the discovery of the Kuiper Belt. He explained that scientists "should have just counted those out and called them dwarf planets." This would allow scientists to retain Pluto as a planet.
One student, Matthew, expressed acceptance of the change. Matthew stated, “I think they should have changed it for people's safety because if they want to go on the Kuiper Belt, something wrong could happen because they're really not planets.” His response suggests that it is fine to reclassify Pluto as a dwarf planet because if it is like the Kuiper Belt objects it may not be as safe for people to visit as the planets would be.

In general, the findings of the analysis on students' responses during the small group discussion support those of the students who were interviewed. Students were more likely to disagree with the reclassification of Pluto even though they understood the rationale for the new definition. The findings also suggest that students in the small group discussion also held constructivist NOS views that were similar to the four students interviewed. Taken together, the findings suggest that these students view science knowledge as changing based on evidence, new discoveries, and scientific debate. It is also likely that these students view scientists as capable of making mistakes and that what we know in science changes based on those mistakes.
CHAPTER 5

DISCUSSION

Introduction

I begin this chapter by summarizing the findings of this study in the context of the research questions. The discussion centers the significance of the results in connection to the role of emotions on students' beliefs about the nature of science, their attitudes towards the scientific point of view, and conceptual change when learning about a controversial topic in science. Recall that conceptual change is the process of gradually restructuring one's prior alternative or naïve conceptions to align with the scientific viewpoint (Mason, in press; Vosniadou 2002). In contrast, attitudes have been described as consisting of beliefs, feelings, and actions (Hynd, 2003). I will also discuss the educational implications of the results in regards to the use of rereading and small group discussions to facilitate engagement with text to promote NOS beliefs, attitude, and conceptual change. I conclude with a discussion of the limitations of this research and suggestions for future research.

Summary of the Findings

The examination of students' responses on the Emotions about Pluto's reclassification survey, as well as the comments from those students who were
interviewed, suggest that emotions are indeed involved when learning about controversial
topics in science. Students experienced a range of emotions related to Pluto’s
reclassification, including happy, surprised, disappointed, and mad. Students commonly
related these emotions to the fact that Pluto had been a planet for a very long time. In
general, students experienced more negative emotions than positive emotions, and those
negative emotions were felt more intensely than the positive emotions. This supports my
hypothesis that students would experience a range of emotions, both positive and
negative, in relation to the topic of Pluto’s reclassification.

The examination of students’ NOS beliefs suggest that these students held fairly
well developed constructivist beliefs. In general, these students viewed science
knowledge as changing and they understood the role of new discoveries and scientific
debate in changing what we know in science. The quantitative analyses failed to show a
relationship between emotions and students’ NOS beliefs, suggesting that NOS beliefs
may not have an affective component.

I had predicted that emotions would be related to students’ NOS beliefs based on
the literature in social psychology that emotions and cognition are highly interrelated
(Zajonc, 1980). Lazarus (1984) postulated that emotions influence how we think. It can
be argued that the relationship between NOS beliefs and cognitive processes was
evidenced as students shared their NOS beliefs during the small group discussions and in
answering the NOS beliefs survey. However, the results of the present study did not bear
out the relationship between emotions and NOS beliefs. These findings, however, are
inconclusive and need to be explored further.
The results suggest that positive and negative emotions are related to students' attitudes about Pluto's reclassification. For example, positive emotions showed a positive association with attitudes, suggesting that students who reported being happy or glad were more accepting of the reclassification. In addition, positive emotions were related to change in students' attitudes towards acceptance of the change to Pluto. It may be the case that students who have positive emotions about a controversial topic, like Pluto's reclassification, may enjoy learning about that topic which may deepen engagement with the new information, increasing the likelihood of attitude change. These findings support my hypothesis that positive emotions would be linked with higher levels of acceptance of Pluto's reclassification than negative emotions, and that these positive emotions may serve to foster attitude change.

Negative emotions were inversely correlated with a forward shift towards acceptance of the reclassification suggesting that students who were irritated or sad were less likely to accept Pluto as a dwarf planet. Negative emotions were also shown to be significantly related to attitude change towards a greater acceptance of the reclassification. It may be the case that negative emotions fostered critical thinking and elaboration (Fiedler, 2000; Linnenbrink, 2006) as students thoughtfully considered the anomalous information presented in the refutation text.

While the shift in acceptance (M = 2.5 to M = 2.9) is enough to show statistical significance, it still does not indicate a full acceptance of the reclassification. This may be due to negative emotions being linked with resistance to attitude change. The findings revealed a general lack of acceptance of the scientists' decision to reclassify Pluto as a dwarf planet. Petty and Cacioppo (1986) argued that individuals are likely to resist
change when the topic is highly personally relevant. In general, students in this study expressed strong personal connections with Pluto. Many students identified Pluto as their favorite planet.

I predicted that negative emotions would be associated with change in attitudes for those students who were willing to critically weigh the ideas presented in the text. I also expected to find that negative emotions would be related to resistance to change for those students who became more deeply entrenched in their initial attitudes. The findings of this study make visible the paradox of the role that negative emotions may be playing in the change process. These findings support the need for further research to explore the role of negative emotions on attitude change when learning about controversial science topics.

Positive and negative emotions were shown to be associated with students’ conceptions of the planets and Pluto’s dwarf status. The findings suggest that positive and negative emotions at posttest were predictive of change in students’ acceptance of Pluto’s dwarf status from pretest to posttest. The significance levels of this relationship between emotions and the conceptual shift towards acceptance of the reclassification can be interpreted with confidence. It may be likely that positive and negative emotions were serving to facilitate critical thinking and elaboration on the information regarding Pluto’s reclassification. This supports my hypothesis that positive and negative emotions related to this topic may increase cognitive engagement as students critically and thoughtfully weighed the information in the text. Both positive and negative emotions may signal the individual to attend more closely to the anomalous information, leading to careful, detailed-oriented processing (Fiedler, 2000; Bless, 2000; Gregoire, 2003). Again, these
findings make visible the paradox of emotions and cognitive processing in that both positive and negative emotions can serve as facilitators of change.

Positive emotions were also shown to be associated with change to students' concepts about the planets from pretest to posttest. A positive correlation was found between positive emotions at posttest and students' ability to correctly identify the planets from pretest to posttest. This finding can be interpreted somewhat confidently based on the significance value. This finding suggests that students who experienced positive emotions were more likely to exclude Pluto from their list of planet names at posttest. It may be likely that positive emotions were facilitating critical thinking about the planets and that Pluto is no longer considered a planet. The results support my prediction that positive emotions would facilitate critical thinking and elaboration which would increase the likelihood of conceptual change. This finding should be interpreted with some caution, however, because positive emotions were not shown to be predictive of students' responses at pretest. Further research is needed to investigate whether this finding holds and whether emotions at pretest can be predictive of students' concepts of planets.

This study shows that it may be possible to increase engagement with refutation texts through rereading and small group discussions. This supports the literature on refutation text as facilitating conceptual change in science learning (Guzzetti et al., 1993; Mason, in press). The results suggest that students experienced significant forward shifts in their constructivist NOS beliefs, their attitudes towards Pluto's reclassification, and the conceptual knowledge about why scientists changed the definition of planet as a result of rereading the text. In addition, students who engaged in small group discussions while
rereading the text had a significant advantage over those in the reread only group for increased and sustained conceptual change. More research is needed to investigate if such changes can be sustained over longer periods of time than in the present study.

The Warming Trend in Science Learning

The purpose of this study was to examine the influence of emotions when learning about a controversial topic in science. I specifically selected the topic of Pluto’s reclassification to a dwarf planet because it has sparked such an emotionally charged debate among scientists and the general population. The reclassification of Pluto to a dwarf planet is also a topic that is emotionally laden for elementary school children. Indeed, many fifth grade students across the globe sent angry email messages to the International Astronomical Union when it was announced that Pluto was no longer a planet. Sixth grade students in most states are required to learn about the solar system, including the planets. The recent reclassification of Pluto provided an avenue to explore the influence of emotions on students’ nature of science beliefs, attitudes, and conceptual change.

The results of this study suggest that emotions are a part of science learning, especially when the topic is controversial. Traditionally, science learning was perceived as a purely rational, “cold” cognitive endeavor. Early models of conceptual change did not include an affective component (Posner et al., 1982). More recently, researchers of conceptual change have called for investigations of “hot” cognitive factors such as affect, interest, and motivation (Pintrich et al., 1993). This study supports the warming trend
(Sinatra, 2005) in conceptual change research as it demonstrates that science learning likely involves emotions and those emotions are influencing whether change occurs.

The educational implications from this study suggest that learning activities and instruction should be carefully designed so that students' emotions can be used as a tool to engage them with the topic. Instructional materials can elicit emotional responses which can act as triggers to promote deep engagement, which in turn, may lead to change in students' NOS beliefs, attitudes, and scientific conceptions.

The overall pattern in the data suggests that students held constructivist beliefs about the nature of science. They understood that science knowledge is tentative, that new discoveries can change what we know in science, and that debates are a part of the scientific process. Past research has shown that students who hold constructivist beliefs about the nature of science are more likely to experience conceptual change when learning about science topics (Leach & Lewis, 2002; Mason & Gava, in press; Qian & Alverman, 2000). What I found in the present study is that even though these students generally held constructivist beliefs about the nature of science, they were resistant to changing their conceptions about Pluto. The negative emotions students experienced in connection to the reclassification of Pluto may have overridden the influence of their NOS beliefs that in other contexts may have been associated with conceptual change.

These students were also resistant to attitude change in their acceptance of Pluto as a dwarf planet. Students reported experiencing primarily negative emotions, and those negative emotions were rated at fairly high levels. It seems likely that these negative emotions may have resulted in students rejecting or ignoring the scientific explanation.
The comments given by students during the small group discussions and interviews also suggest that these students were holding back on their willingness to accept Pluto as a dwarf planet until the scientists had collected more evidence to justify the reclassification. Chinn and Brewer (1993) argued that individual’s responses to anomalous data often include similar responses such as ignoring or rejecting it, or holding the conflicting information in abeyance until more compelling evidence is provided. It is likely that the negative emotions present in this study were related to these types of responses, which in turn led to an overall low level of acceptance of the now dwarf-planet Pluto. Further research is needed to explore the relationship between negative emotions and these responses of resistance.

It is important to note that these students experienced a statistically significant shift in their attitudes towards Pluto’s reclassification, even in the face of negative emotions. The results suggest that students’ attitudes about a controversial science topic can be changed through instruction. Rereading the refutation text facilitated the attitude shift among most students. It may be the case that negative emotions promoted deeper engagement with the ideas presented in the text. Conceptual change researchers have argued that cognitive dissonance can increase the likelihood of change (Dole & Sinatra, 1998; Gregoire, 2003; Posner et al., 1982). It is plausible to suggest that negative emotions were associated with the cognitive dissonance students experienced as they grappled with the anomalous data. It may be that negative emotions facilitated deeper engagement with the information in the text which in turn, promoted the shift towards acceptance.
This study makes visible the paradox that exists in the literature regarding emotions and cognition. Researchers have argued that negative emotions can impede cognitive processing but that they can also foster critical thinking, elaboration, and metacognition (Gregoire, 2003; Lazarus, 1982; Linnenbrink, 2006). Similarly, positive emotions have been linked with superficial cognitive processing and with more detail-oriented processing if the individual notices a discrepancy between their existing beliefs and the new information (Bless, 2000; Fiedler, 2000). Further research is needed to better understand this paradox of emotions and how different emotions may influence cognitive processing in relation to conceptual change.

From an educational standpoint, this study suggests that positive and negative emotions can facilitate the complex process of change in students’ NOS beliefs, attitudes, and concepts about science. From a practical standpoint, I am not advocating for teachers to promote feelings of anger or frustration among their students as a teaching tool. However, the findings of this study suggest that these emotions can be present when learning about controversial topics. Moreover, it is possible that these emotions can lead to critical thinking and elaboration which increases the likelihood of change. It is also important to acknowledge the presence of negative emotions when learning about controversial topics because these emotions may contribute to students’ attitudes of resistance towards the scientific explanation and resistance to conceptual change.

It is also possible that students’ shift towards acceptance was related to the conceptual change they experienced regarding the new definition of planet. Prior to the study, students generally held misconceptions of why scientists changed the definition. After the intervention, students’ conceptions about the new definition reflected an
increased understanding of the scientific explanation. It may be the case that students' attitudes towards the reclassification of Pluto shifted because they understood more clearly the reasons behind the scientists' decision. This relationship is speculative and warrants further investigation to see if it bears out with other sample populations.

The findings also suggest that attitude change may be easier to achieve than conceptual change when learning about controversial topics in science. The overall trend in students' attitudes shifted towards acceptance of Pluto's dwarf status after rereading the text. However, students tended to be more resistant to conceptual change. The analysis of the conceptual change items revealed that the refutation text was relatively ineffective in changing students' conceptions about the number of planets in the solar system. Students often included Pluto in their list of the planets.

In addition, the refutation text failed to promote change in students' scientific understanding of why scientists no longer classify Pluto as a planet. It could be that the scientific rationale that Pluto's size, shape, and orbit may have been too complex for students to understand from the information contained in just one text. It is also plausible that negative emotions and students' lack of acceptance of Pluto's dwarf status may have contributed to the resistance to conceptual change. The negative emotions and general lack of agreement with the change to Pluto may have filtered students' cognitive engagement with the scientific explanation. It is possible that students rejected or ignored the information presented in the text because it explicitly contradicted their prior beliefs.

This study supports research that shows conceptual change as a gradual, complex process that typically occurs over an extended period of time (Hatano & Inagaki, 2003; Mason, in press; Vosniadou, 2007). Deeper understanding of a controversial topic, such
as Pluto’s reclassification, requires more learning activities than two readings of a text. Specifically, the students who participated in the small group discussions around the text did not show an advantage over those who reread the text for experiencing conceptual change regarding why Pluto is no longer classified a planet. This may be due to the small group discussion lasting only 20 minutes, which may not be sufficient to go into much depth on a complex topic such as the history of the new definition of planet and Pluto’s dwarf status.

Fostering Engagement to Facilitate Change

Conceptual change researchers have suggested that deeper cognitive engagement with a message increases the likelihood of change (Dole & Sinatra, 1998). For the current study I purposefully selected instructional techniques that researchers have shown to be effective in increasing cognitive engagement (see for example Beck & McKeown, 2006; Amlund et al., 1986). I wanted to explore whether engagement with the ideas about a controversial topic could be deepened through the rereading of a refutation text. I also wanted to investigate whether engagement could be increased through rereading a refutation text in small group discussions.

I chose to use a refutation text as a productive starting point (Mason, in press) for facilitating change in students’ NOS beliefs, attitudes towards Pluto’s reclassification, and concepts about planets and Pluto. This study supports past research has shown that refutation texts are effective in promoting conceptual change (Diakidoy et al., 2003; Guzzetti et al., 1993; Hynd et al., 1994; 1997; Mason & Gava, in press). One possible reason for the effectiveness of refutation texts is the way the information is presented to
the reader. The text states a common misconception, directly refutes the misconception, and provides the scientific explanation as a plausible and fruitful alternative (Hynd, 2001).

One implication of the present study is that rereading refutation texts can facilitate change in students’ NOS beliefs, attitudes, and scientific knowledge. This style of text can be utilized in the classroom to help promote change when learning about controversial topics in science. An additional implication for teacher educators is that preservice teachers should have the opportunity to learn about the power of refutation texts for promoting NOS beliefs, attitudes, and conceptual change.

It is most likely that students will need more than one exposure to a text if conceptual change is to be achieved (Mason, in press). This may especially be the case when learning about emotionally charged topics in science such as Pluto’s recent reclassification. I decided to have students reread the refutation text to provide them with more opportunities to thoughtfully consider the information related to the new definition of planet and Pluto’s subsequent reclassification. I also chose to use the small group discussion format Questioning the Author (Beck & McKeown, 2006) as a way to increase the likelihood of change over rereading the text independently.

This study supports the Cognitive Reconstruction of Knowledge Model that the interaction between the message and the learner is central to the change process, and that deeper engagement with a text increases the likelihood of change (Dole & Sinatra, 1998). Students in both conditions benefited from rereading the refutation text. Rereading the refutation text helped to facilitate change in students’ beliefs towards more constructivist
views on the nature of science. In addition, rereading the text helped to facilitate the forward shift in students’ attitudes of acceptance towards Pluto’s dwarf planet status.

Past research has demonstrated that engagement with text can be increased through rereading (Amlund et al., 1986). Rereading the text resulted in students’ changing their previously held misconceptions about why the definition of planet was changed. It can be speculated that rereading the refutation text facilitated this change in students’ scientific conceptions. Moreover, the study suggests that engagement can be enhanced even more deeply when students engage in small group discussions while rereading the text. It may be that students will attend more closely to the important ideas in a text when they participate in small group discussions than when they reread the text independently.

The specific format of the small group discussion may also have helped to promote conceptual change in students’ understanding of what prompted the new definition of planet. I selected Questioning the Author (Beck & McKeown, 2006) because it allowed me to determine the direction of the discussion by the questions I asked. The questions I posed to the students were aimed specifically at highlighting the main ideas in the text. This was intended to help increase students’ engagement with those ideas as they wrestled with the scientific explanation. The findings suggest that teacher-led small group discussions can help to promote conceptual change when students are learning about emotionally charged topics in science.

Refutation text and small group discussions can facilitate conceptual change when learning about controversial topics in science. Historically, teachers have relied on textbooks as the source of information for teaching students science content. Researchers
have argued that elementary science textbooks can convey science information but they are limited in their capacity to engage students in science processes (Appleton, 2007). More recently, the shift in science education has emphasized inquiry-centered practices involving hands-on activities (NRC, 1996) with less of an emphasis on reading texts for science learning (Settlage & Southerland, 2007). This study shows that texts can be effective in promoting change in students’ NOS beliefs, attitudes, and conceptual knowledge. More specifically, rereading a refutation text in small group discussion formats may help students to understand controversial science topics.

The results of this study suggest that it is possible to increase engagement about controversial topics through rereading refutation texts and small group discussions. Reading a refutation text a second time may help students recognize any discrepancies between their prior knowledge and the new information. Rereading the refutation text may also provide students the opportunity to reflect more deeply on the scientific explanation, which increases the likelihood of conceptual change (Dole & Sinatra, 1998). Students’ misconceptions and attitudes of resistance may be dislodged through rereading the refutation text.

The small group discussions may also be effective in fostering cognitive engagement that can lead to conceptual change because students have the opportunity to ask questions related to the main ideas. In addition, students are able to share their ideas with one another and thoughtfully and critically discuss those ideas with one another. The results of this study suggest that the small group discussion format facilitated students’ use of logical reasoning as they attempted to make sense of the reasons behind the new definition of planet and the subsequent reclassification of Pluto. The small group
discussions may serve as an avenue for dislodging students’ misconceptions through the exchanging of ideas and feedback from the others in the group.

The dialogue in the small group discussions can also provide the teacher with insights to students' conceptions, including any misconceptions that may arise as a result of reading the text. The teacher is able to provide immediate and direct feedback to students during the discussion to help them understand the scientific explanation.

An educational implication of these findings suggests that small group discussions during the rereading of a refutation text can be incorporated into science learning activities. Change in students’ nature of science beliefs, attitudes towards the scientific point of view, and conceptual knowledge can be promoted through small group discussions. Rereading a text independently may not be sufficient for promoting conceptual change, especially when learning about a controversial topic in science. Small group discussions can increase engagement with the main ideas of the text. Carefully planned questions targeted to focus students’ thinking on the main ideas can foster rich discussions among students which can lead to critical reflection and elaboration on those ideas. The focus questions can also be developed to elicit students’ misconceptions which the teacher can refute through careful explanation.

An additional educational implication is that attitude change and conceptual change can be fostered through carefully planned instruction. It may be possible to promote attitude change through conceptual change. As students come to understand the scientific explanation for the controversial topic, they may experience an increased level of acceptance towards the scientific explanation. Science education researchers (Southerland, 2000; Southerland et al., 2001) and the National Academy of Sciences
(1998) suggest that it is important for teachers to aim for understanding the scientific explanation without requiring students to accept the explanation. Science instruction can be developed to promote conceptual understanding, which may in turn lead to increased levels of acceptance.

Limitations of the Study

A limitation for the current study is that students were primarily from White, upper-middle class families. Past research has shown that students from these types of families are generally successful in academic settings (National Research Council, 1998). In addition, the students in the present study were enrolled in a private school. The results of this study may reveal a different trend across more diverse student populations. In addition, the sample size was relatively small. Further research is warranted to investigate whether these findings would be replicated with larger sample sizes and different student populations.

A second limitation of this study is that the intervention was constrained by time. I was fortunate to be welcomed into classrooms by the teachers and students. The participating teachers were generous in their willingness to allow me to utilize four hours of their classroom instructional time over a two week period. In general, the amount of time was sufficient for conducting the intervention. However, in the context of authentic science learning units, more time and instruction would be provided for students to engage with the discipline materials. It was challenging to engage students in in-depth discussion around the refutation text during one brief, 20-minute session. This may account for the lack of any significant advantage for the discussion group over the
rereading group in NOS beliefs, attitudes, and most of the conceptual change items.
Conceptual change is a gradual, effortful process (Mason, 2007). Students may have
experienced greater levels of change across the three constructs had they been given more
opportunities to engage with the materials (Diakidoy et al., 2003).

A third limitation of this study was the time on task difference between the two
groups. It is clear that students who reread the text independently at their desks had less
time on task than those who participated in the small group discussions. In future studies,
an additional task will be developed to better equalize the time on task between the
experimental and control groups.

A fourth limitation to this study is in relation to the measuring of students’
emotions. I used self-report surveys based on measures developed by researchers in this
field of study (Pekrun et al., 2002; 2005). As has been argued, emotions must be
measured in the moment because they are intense, brief responses to a specific referent
(Linnenbrink, 2005). The self-report measures used in this study captured students’
emotional responses as close to the moment as possible but not on-line and in the
moment. Future research is needed to develop more effective ways of identifying
student’s emotions as they occur.

Future Research

This study documents the role of emotions, one of the “hot” factors considered to
be an influencing resource on the complex process of conceptual change (Pintrich et al.,
1993). This line of research is relatively new; therefore, much research is needed to
examine the influence of emotions on the change process, especially when learning about controversial topics in science.

In the present study I was able to explore one of the two dimensions of emotions as described by Pekrun and colleagues (2002), that of valence. Further research is needed to examine the influence of the second dimension of emotions, both activating and deactivating. The study suggests that positive and negative emotions may have acted to facilitate critical thinking and elaboration but they may also have served to impede such cognitive processes. An investigation of the dimension of activating/deactivating emotions may provide an avenue for a finer grained analysis of the ways in which positive and negative emotions are influencing the change process. It may also help to reveal the influence of the emotion of surprise when learning about controversial science topics.

Further research is also needed to investigate the types of emotions involved when learning about other controversial topics in science such as stem cell research and genetically engineered foods. This research may help to uncover which negative and positive emotions are present and how those emotions might be influencing the change process. Patterns of emotions across various controversial topics may lead to deeper understanding of how emotions may promote or impede deeper cognitive engagement with the scientific explanation.

Research is also needed to examine the interplay of additional “hot” factors (Pintrich et al., 1993) of conceptual change and emotions. For example, investigations could examine how interest may influence the types of emotions present when learning about controversial topics. The findings of the current study suggest that positive and
negative emotions are both present in such learning contexts. Little research has been conducted to investigate the types of emotions related to interest, and how those two constructs may be influencing the change process.

The results of this study suggest that attitudes of resistance are present when learning about controversial science topics. Students may tend to respond to anomalous data by rejecting, ignoring, or holding it in abeyance until they perceive the scientific explanation to be compelling and plausible (Chinn & Brewer, 1993). Future research is needed to investigate the relationship between negative emotions and the responses of resistance that may be present when learning about controversial topics.

The implications of this study suggest that attitude shift may be related to conceptual change. Further research is warranted to explore whether any significant relationship exists between these two constructs. One question that could be addressed in future research is, “As students come to understand the scientific explanation around a controversial topic, will they be more likely to accept it?” This may lead to greater insights about the conceptual change process and its relationship with attitude change. Such research may also help science educators develop curriculum that promotes understanding of science content in a way that may also lead to acceptance of the scientific explanation.

In sum, the findings of the present study support the “warming trend” (Sinatra, 2005) in conceptual change research, indicating that “hot” factors such as emotions are involved in the complex process of conceptual change. This study adds to the literature that follows the “warming trend” as a way of increasing our understanding of the complex factors involved with conceptual change and learning in the science classroom.
Emotions may serve to facilitate deeper engagement with the anomalous data, but they can serve to impede engagement as well. Emotions may override the influence of constructivist NOS beliefs on the change process. Emotions may also act to foster resistance to change. However, the implications of this study also suggest that emotions can promote deeper cognitive engagement such as critical thinking and elaboration which increases the likelihood of change.

The implications of this study also support conceptual change models that emphasize the central role of engagement in the change process (Dole & Sinatra, 1998; Grégoire, 2003). Increased cognitive engagement with the message in the text can be fostered through carefully designed texts and learning activities. For example, refutation texts can be used to trigger critical thinking and detail-oriented processing of the important ideas and scientific explanation. Engagement can also be enhanced through rereading the text or participating in small group discussions around the text. Deeper cognitive engagement facilitated through these types of instructional interventions may increase the likelihood of change.

From an educational standpoint, this study highlights the influence of emotions on the change process when learning about controversial science topics. Instructional materials and activities must be designed so as to use these emotions in service of the change process. Positive and negative emotions can be used as an avenue for developing student's engagement with the content. Teachers must also be aware of negative emotions that may act as barriers to the change process and develop materials and activities that may help to soften those types of emotional responses. Students' emotions are only one of the “hot factors” that have been shown to influence the process of change.
on NOS beliefs, attitudes towards scientific explanations, and their conceptual knowledge of science in the classroom.
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role of motivational beliefs and classroom contextual factors in the process of


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*Table 1*

*Design of the Study*
Table 2
Participant Demographics for the Experimental and Control Groups

Reread plus Discussion (Experimental)

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Reread only (Control)

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**Table 3**

*Homogeneity of Variance Analyses Significance Levels*

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<td>Time 3 $p = .619$</td>
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* *Box's test of equality of covariance was not computed because there were fewer than two nonsingular cell covariance matrices.*
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* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)
Table 6
*Means and Standard Deviations for Attitudes about Pluto*

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* Items scored on rubric (0 = non-scientific, 1 = scientific, 2 = scientific, elaborated)
Table 9
Pearson Correlations between Emotions and NOS Beliefs, Concept Items 1 and 2

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<th>Concept 2</th>
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<td>Posttest r</td>
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<td>Pretest r</td>
<td>Posttest r</td>
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<td>Negative Emotions, Pretest</td>
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<td>.18</td>
<td></td>
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<td>.013</td>
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<td>N</td>
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<td>Item 3, Posttest</td>
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* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)
Table 11

*Spearman rho Correlations between Emotions and Concept Items 4, 5, and 6*

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<th>Concept 5</th>
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<th>Concept 6</th>
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<td>Posttest $r_s$</td>
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<td>Pretest $r_s$</td>
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*Correlation is significant at the 0.05 level (2-tailed)*
Table 12

Linear Regressions for Emotions Predicting NOS Beliefs and Attitudes

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<th>$SE B$</th>
<th>$\beta$</th>
<th>$p$</th>
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<td>.096</td>
<td>.076</td>
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<td>.073</td>
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<td>.199</td>
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<td>.967</td>
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<td>.611</td>
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* Prediction is significant at the $p = .01$ level
** Prediction is significant at the $p < .01$ level
Table 13  
*Linear Regressions for Emotions Predicting Concept Knowledge, Items 1, 2, 3*

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<th>$\beta$</th>
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* Prediction is significant at the $p < .05$ level
** Prediction is significant at the $p < .01$ level
Table 14

*Ordinal Regression Analyses for Emotions Predicting Concept Knowledge, Items 4, 5, 6*

<table>
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*. Prediction is significant at the $p < .05$ level
Table 15
Absolute Change Variables Pretest to Posttest for Beliefs, Attitudes, and Concept Items
Means and Standard Deviations

<table>
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Table 16

*Linear Regressions for Negative Emotions Predicting Absolute Value of Change*

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* Prediction is significant at the $p = .01$ level
** Prediction is significant at the $p < .01$ level
Table 17

*NOS Beliefs and Attitudes Means and Standard Deviations by Group*

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*Concept Items 1 and 2 Means and Standard Deviations by Group*

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<td>Posttest</td>
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Content Analysis on Student Interviews, Emotions and Attitudes

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<td>Shocked Just kind of shocked</td>
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<td>Frustrated Always been a planet</td>
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Table 22

*Content Analysis on Student Interviews, Nature of Science Beliefs*

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### Table 23
*Componental Analysis of Student Interviews*

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**Frequencies**

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<td>proven different</td>
<td>don’t get rid of it</td>
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<td>scientists wrong</td>
<td>mess up your mind</td>
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<td>Rationale</td>
<td>Participant</td>
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<tr>
<td>Disagree</td>
<td>Always been a planet</td>
<td>Jim</td>
<td>They shouldn’t have changed the definition because then we would have 9 how it always was.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always been a planet</td>
<td>Jaime</td>
<td></td>
<td>I wouldn’t really know what to say except for the fact that I have grown up with Pluto being a planet. I’m just used to having 9 planets.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Always been a planet</td>
<td>Jaime</td>
<td></td>
<td>We’ve all grown up with Pluto as a planet. So when they told us it was gone, I kind of didn’t believe that because I’ve just grown up with it as a planet.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pluto’s traits are fine</td>
<td>Todd</td>
<td></td>
<td>I think that Pluto should still be a planet. It doesn’t matter what size it is. I think it’s okay if it shares Neptune’s orbit.</td>
<td></td>
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</tr>
<tr>
<td>Pluto’s traits are fine</td>
<td>Josh</td>
<td></td>
<td>I think they shouldn’t downsize Pluto because even though it crosses into Neptune’s orbit it has two of three. I think that even though it crosses, I just think it should be. Because if it just crosses at one or two spots I think that’s okay. Because the only problem would be if it collided. But I don’t think that will ever happen.</td>
<td></td>
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</tr>
<tr>
<td>Pluto’s traits are fine</td>
<td>Elizabeth</td>
<td></td>
<td>I think it should still be a planet. Even though it goes into Neptune’s orbit it still has a round shape and I don’t think it has to attract solar objects to be classified as a planet.</td>
<td></td>
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</tr>
<tr>
<td>Pluto’s traits are fine</td>
<td>Randy</td>
<td></td>
<td>I think Pluto should still be a planet because it might be in Neptune’s orbit, but it’s not like the moon and the Earth. Because the moon revolves around the Earth, but Pluto goes through Neptune’s path and it doesn’t even go near Neptune the rest of the time.</td>
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</table>
Table 27  
*Content Analysis of Small Group Discussion, Student's Attitudes: Dwarf Planet*

<table>
<thead>
<tr>
<th>Attitude</th>
<th>Rationale</th>
<th>Participant</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disagree</td>
<td>New objects can be dwarf planets</td>
<td>Jim</td>
<td>I think they should have just counted those out and called them dwarf planets.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jaime</td>
<td>And Pluto is my favorite planet besides Earth. So I've always like it to be a planet. And once they declared it not a planet I freaked out!</td>
</tr>
<tr>
<td></td>
<td>Favorite planet</td>
<td>Jaime</td>
<td>We shouldn't change our beliefs because sometimes they can be wrong</td>
</tr>
<tr>
<td></td>
<td>Scientists can be wrong</td>
<td>Jaime</td>
<td>As long as people go on it and they are still making ways for people to live on different planets. Like on Mars, how they are trying to find life, in case there is.</td>
</tr>
<tr>
<td></td>
<td>Future exploration</td>
<td>Todd</td>
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</tr>
<tr>
<td>Agree</td>
<td>Safety</td>
<td>Matthew</td>
<td>I think they should have changed it for people's safety because if they want to go on the Kuiper Belt something wrong could happen because they're really not planets.</td>
</tr>
</tbody>
</table>
Figure 1. Group Means of NOS Beliefs.

![Bar graph showing group means of NOS beliefs across pretest, posttest, and delayed posttest comparisons. The graph compares Reread and Discussion conditions.](image-url)
Figure 2. Group Means of Attitudes.
Figure 3. Group Means of Concept Item 6.
APPENDIX
APPENDIX A

EMOTIONS ABOUT PLUTO’S RECLASSIFICATION

When people first heard that Pluto was no longer a planet, they may have had a lot of
different feelings about it. We’re interested in how you felt when you first found out that
Pluto is no longer a planet. Think back to how you felt when you first found out that
Pluto is no longer a planet. You, too, may have felt more than one way about it, so please
think carefully about each question listed below.

The items below list several emotions that you may have felt when you first heard that
Pluto is no longer a planet. Please read the sentence. Then, for each emotion circle the
number that best describes how you felt.

Sentence: When I first heard that Pluto is no longer a planet, I felt:

1. Joyful
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree

2. Uneasy
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree

3. Worried
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree

4. Surprised
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree

5. Happy
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree

6. Disappointed
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree

7. Excited
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree
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<td>9. Mad</td>
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<td>10. Scared</td>
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<td>11. Irritated</td>
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<td>12. Sad</td>
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<td>13. Upset</td>
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<td>14. Nervous</td>
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<td>disagree</td>
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<td>agree</td>
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<td>17. Frustrated</td>
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You've now had a chance to read more about the scientists' decision to change Pluto's status as a planet. We're interested in your current feelings about this decision. When you answer the questions below, please indicate how you feel right now about the decision that Pluto is no longer a planet. Remember, it's okay to feel more than one way as you think about the scientist's decision.

Please read the sentence below. Then, for each emotion, circle the number that best describes how you feel right now about this decision.

Sentence: Now that I've read about why Pluto is no longer a planet, I feel:

1. Joyful
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree

2. Uneasy
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree

3. Worried
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree

4. Surprised
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree

5. Happy
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree

6. Disappointed
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree

7. Excited
   - strongly disagree
   - disagree
   - unsure
   - agree
   - strongly agree
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<td>10. Scared</td>
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<td>11. Irritated</td>
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<td>16. Bored</td>
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<tr>
<td>17. Frustrated</td>
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<td>18. Annoyed</td>
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APPENDIX C

ATTITUDES ABOUT PLUTO

Please mark how strongly you agree or disagree with each of the statements listed below. Please circle the number that best matches the strength of your attitude.

1. The scientists’ decision to change Pluto from a planet to a dwarf planet was a good one.
   
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<th>disagree</th>
<th>unsure</th>
<th>agree</th>
<th>strongly agree</th>
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2. Pluto should remain a planet.
   
<table>
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<th>disagree</th>
<th>unsure</th>
<th>agree</th>
<th>strongly agree</th>
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3. Pluto as a dwarf planet is okay with me.
   
<table>
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<tr>
<th>strongly disagree</th>
<th>disagree</th>
<th>unsure</th>
<th>agree</th>
<th>strongly agree</th>
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4. Defining Pluto as a dwarf planet because of its size, shape and orbit is okay with me.
   
<table>
<thead>
<tr>
<th>strongly disagree</th>
<th>disagree</th>
<th>unsure</th>
<th>agree</th>
<th>strongly agree</th>
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</table>

5. Scientists should accept Pluto as one of the nine planets.
   
<table>
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<tr>
<th>strongly disagree</th>
<th>disagree</th>
<th>unsure</th>
<th>agree</th>
<th>strongly agree</th>
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APPENDIX D

CONCEPTS ABOUT PLANETS

Please provide a short answer (2 or 3 sentences) to each of the following questions.

1. How many planets are in our solar system?

2. List the planets in our solar system:

3. Should Pluto still be a planet?

4. Explain your answer to question #3:

5. Why do scientists no longer call Pluto a planet?

6. Why did scientists change the definition of planet?
APPENDIX E

BELIEFS ABOUT THE NATURE OF SCIENCE

Please mark how strongly you agree or disagree with each of the statements listed below. Please circle the number that best matches the strength of your belief.

1. All questions in science have only one right answer.
   
   strongly disagree  disagree  unsure  agree  strongly agree
   
   1  2  3  4  5

2. Scientific knowledge is always true.
   
   strongly disagree  disagree  unsure  agree  strongly agree
   
   1  2  3  4  5

3. There are some questions that even scientists cannot answer.
   
   strongly disagree  disagree  unsure  agree  strongly agree
   
   1  2  3  4  5

4. Scientists always agree about what is true in science.
   
   strongly disagree  disagree  unsure  agree  strongly agree
   
   1  2  3  4  5

5. New discoveries can change what scientists think is true.
   
   strongly disagree  disagree  unsure  agree  strongly agree
   
   1  2  3  4  5

6. Sometimes scientists change their minds about what is true in science.
   
   strongly disagree  disagree  unsure  agree  strongly agree
   
   1  2  3  4  5

7. Once scientists have the result of an experiment, that becomes the only answer.
   
   strongly disagree  disagree  unsure  agree  strongly agree
   
   1  2  3  4  5

8. Scientists know pretty well everything about science; there is not much more to know.
   
   strongly disagree  disagree  unsure  agree  strongly agree
   
   1  2  3  4  5

9. Ideas in science sometimes change.
   
   strongly disagree  disagree  unsure  agree  strongly agree
   
   1  2  3  4  5
10. The ideas in science books sometimes change.
   strongly disagree  disagree  unsure  agree  strongly agree
   1  2  3  4  5

11. The most important part of doing science is arriving at the right answer.
   strongly disagree  disagree  unsure  agree  strongly agree
   1  2  3  4  5

12. Some ideas in science today are different than what scientists used to think.
   strongly disagree  disagree  unsure  agree  strongly agree
   1  2  3  4  5
Some people believe that basic ideas in science do not change. Some people also think that scientists just add newly discovered information to those ideas without changing them. However, new discoveries can change what scientists think is true. Basic science knowledge can change as new information is discovered. For example, scientists once thought the Earth was flat. This view changed when Magellan, a European explorer, sailed around the Earth. Scientists then changed their views about Earth’s shape.

What we know from science changes even today. A recent example is the change in the definition of planet. In the past, scientists defined planets as having three qualities. First, planets orbit the Sun. Second, planets shine by reflecting the Sun’s light. Third, planets are larger than asteroids. This meant there were nine planets in our solar system. These were Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.

During the 1980s scientists discovered the Kuiper Belt. The Kuiper Belt is made up of hundreds of large icy objects in our solar system. The objects are larger than asteroids and they orbit the Sun. They shine by reflecting the Sun’s light. Many scientists thought it was necessary to change how we define planets because of this discovery. Otherwise we would have hundreds of planets in our solar system!

In 2006, scientists from around the world met to debate the definition of planet. Scientists changed the definition of planet. Planets have three key features. First, a planet orbits the Sun. Second, a planet is large enough to have formed into a round shape. Third, a planet is the only large object in its orbit. This new definition leaves only eight planets. These are: Mercury, Venus, Mars, Earth, Jupiter, Saturn, Uranus, and Neptune. Earth is
considered a planet because it (1) orbits the Sun, (2) is round, and (3) is the only large
object in its orbit.

Many people think Pluto is a planet. Based on this new definition, Pluto is no
longer a planet! Pluto does not have all three features of a planet. Yes, Pluto orbits the
Sun. But, a planet must have its own orbital path around the Sun. Pluto’s orbit crosses
over Neptune’s orbit!

The new definition also says that planets must be large enough to attract other
solar objects. This means that objects like asteroids and comets orbit the planet. For
example, the Earth is large enough to have pulled the moon into its orbit. However, Pluto
is too small to attract objects to orbit it. Instead, these solar objects share Pluto’s orbit. As
a result, Pluto is not the only large object in its orbit around the Sun. This means Pluto is
not a planet!

Scientists have classified Pluto as a “dwarf planet.” This is because it does not
have all three features of a planet. Pluto may not be the only dwarf planet in our solar
system. Scientists think there are many more dwarf planets yet to be discovered.

Some scientists did not agree with the new definition of planet. In fact, some
scientists think Pluto should still be called a planet. These disagreements between
scientists are a common part of how science works. Scientists do not always agree with
each other about scientific ideas. Sometimes disagreements cause scientists to search for
new information to help them better understand the world we live in.
APPENDIX G

STUDENT INTERVIEW QUESTIONS

1. How did you feel when you first heard about Pluto no longer being considered a planet?

2. After reading the text, how did you feel about Pluto being classified as a dwarf planet?

3. How do you feel now about Pluto being a dwarf planet?

4. What did you know about how scientists decided to rewrite the definition of planet before reading the text?

5. After reading the text, what do you understand about the ways scientists make decisions?

6. Does science knowledge change? If so, how do scientists decide to make those changes?

7. How do scientists use evidence to make decisions?

8. Do scientists always agree with each other?
APPENDIX H

DEMOGRAPHICS

Please complete the following questions. Remember that all information is identified by number only and your complete confidentiality is assured.

1. What is your gender? Mark one. Female [ ] Male [ ]

2. What is your age? __________

3. Please place a check next to the ethnicity listed below that best represents how you identify yourself:
   _____ American Indian/Alaskan Native
   _____ Asian/Asian American
   _____ African American/Black
   _____ Caucasian/White
   _____ Hispanic/Latino/Chicano
   _____ Other: _____________________

4. Do you speak any languages other than English? Yes [ ] No [ ]

5. If you do speak any languages other than English, please write them on the line below.

_________________________________________
## APPENDIX I

### QUESTION THE AUTHOR DISCUSSION

<table>
<thead>
<tr>
<th>Text segment</th>
<th>Queries</th>
<th>Purpose for queries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some people believe that basic ideas in science do not change. Some people also think that scientists just add newly discovered information to those ideas without changing them. However, new discoveries can change what scientists think is true.</td>
<td>What is the author telling us?</td>
<td>Initiate discussion and to help students’ focus their attention on the changing nature of science.</td>
</tr>
<tr>
<td></td>
<td>What do you think about that?</td>
<td>To elicit students’ conceptions about the changing nature of science</td>
</tr>
<tr>
<td>Basic science knowledge can change as new information is discovered. For example, scientists once thought the Earth was flat. This view changed when Magellan, a European explorer, sailed around the Earth. Scientists then changed their views about Earth’s shape.</td>
<td>What do you think the author is telling us about science theories this time?</td>
<td>To help students’ build a coherent understanding of the changing nature of science as well as the role of evidence used in science theories.</td>
</tr>
<tr>
<td>What we know from science changes even today. A recent example is the change in the definition of planet. In the past, scientists defined planets as having three qualities. First, planets orbit the Sun. Second, planets shine by reflecting the Sun’s light. Third, planets are larger than asteroids. This meant there were nine planets in our solar system. These were Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.</td>
<td>What does the author tell us about the Kuiper Belt?</td>
<td>To help students’ understand the role that new discoveries and evidence play in scientific theories.</td>
</tr>
<tr>
<td></td>
<td>How do you think that fits in with what the author told us about planets?</td>
<td>To help students’ understand why scientists’ thought the definition of planets needed to be changed.</td>
</tr>
<tr>
<td></td>
<td>What do you think about that?</td>
<td>To elicit students’ conceptions about planets</td>
</tr>
</tbody>
</table>
During the 1980s scientists discovered the Kuiper Belt. The Kuiper Belt is made up of hundreds of large icy objects in our solar system. The objects are larger than asteroids and they orbit the Sun. They shine by reflecting the Sun’s light.

| How do you think that fits in with what the author has told us about science knowledge? | To help students’ continue to construct a coherent representation of the changing nature of science. |
| What do you think about that? | To elicit students ideas about the use of evidence and the changing nature of science |

Many scientists thought it was necessary to change how we define planets because of this discovery. Otherwise we would have hundreds of planets in our solar system!

| What is the author trying to tell us here? | Continue building a deep understanding of the changing nature of science, including the use of debate among scientists |

In 2006, scientists from around the world met to debate the definition of planet.

Scientists changed the definition of planet. Planets have three key features. First, a planet orbits the Sun. Second, a planet is large enough to have formed into a round shape. Third, a planet is the only large object in its orbit.

| What has the author told us about planets? | To help students understand the central characteristics of planet. |
| How does this connect to what the author has told us before? | To help students understand use of evidence and the changing nature of science |
| What do you think about that? | To elicit students ideas about the use of evidence and the changing nature of science |

This new definition leaves only eight planets. These are: Mercury, Venus, Mars, Earth, Jupiter, Saturn, and Neptune. Earth is considered a planet because it (1) orbits the Sun, (2) is round, and (3) is the only large object in its orbit.

| How does this fit in with what the author told us before? | To help students continue to build a coherent representation of the changing nature of science. |
| What do you think about that? | To reinforce the characteristics of planet. |
| | To elicit students’ ideas about NOS and planets |
Many people think Pluto is a planet. Based on this new definition, Pluto is no longer a planet! Pluto does not have all three features of a planet. Yes, Pluto orbits the Sun. But, a planet must have its own orbital path around the Sun. Pluto’s orbit crosses over Neptune’s orbit!

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What has the author told us now about Pluto?</td>
<td>To reinforce concepts about Pluto and the rationale for changing its classification from a planet to a dwarf-planet</td>
</tr>
<tr>
<td>What do you think about that?</td>
<td>Also, to reinforce the changing nature of science based on evidence</td>
</tr>
</tbody>
</table>

The new definition also says that planets must be large enough to attract other solar objects. This means that objects like asteroids and comets orbit the planet. For example, the Earth is large enough to have pulled the moon into its orbit. However, Pluto is too small to attract objects to orbit it. Instead, these solar objects share Pluto’s orbit.

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<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the author telling us here? How does this fit in with what the author told us about planets attracting other solar objects?</td>
<td>Clarify the concept that planets are the only large object in their orbit around the Sun. Clarify the concept that Pluto is too small to pull in solar objects to orbit around it rather than the Sun.</td>
</tr>
<tr>
<td>What do you think about that?</td>
<td></td>
</tr>
</tbody>
</table>

As a result, Pluto is not the only large object in its orbit around the Sun. This means Pluto is not a planet!

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does this fit in with the new definition of planet? What do you think about this?</td>
<td>Reinforce the concept that Pluto shares its orbit around the Sun with other solar objects.</td>
</tr>
</tbody>
</table>

Scientists have classified Pluto as a “dwarf planet.” This is because it does not have all three features of a planet. Pluto may not be the only dwarf planet in our solar system. Scientists think there are many more dwarf planets yet to be discovered.

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<tbody>
<tr>
<td>How does this fit in with what the author told us about science theories?</td>
<td>Reinforce the use of evidence and new discoveries in the changing nature of science.</td>
</tr>
</tbody>
</table>

Some scientists did not agree with the new definition of planet. In fact, some scientists think Pluto should still be called a planet.

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<tr>
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</tr>
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<tbody>
<tr>
<td></td>
<td>Extend students’ understanding of the changing nature of science to include the role of debate among scientists</td>
</tr>
</tbody>
</table>
These disagreements between scientists are a common part of how science works. Scientists do not always agree with each other about scientific ideas. Sometimes disagreements cause scientists to search for new information to help them better understand the world we live in.

| These disagreements between scientists are a common part of how science works. Scientists do not always agree with each other about scientific ideas. Sometimes disagreements cause scientists to search for new information to help them better understand the world we live in. | So, what do you think that means? | To help students construct a coherent representation of the changing nature of science including debate and the search for better understanding of phenomenon. | What do you think about that? |

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APPENDIX J

THE BIG NEWS

On August 24, 2006, the International Astronomical Union (IAU) General Assembly, which is a group of astronomers and scientists who study the solar system, made a decision to change the definition of planet. The IAU agreed that a planet is defined as a solar object that (a) orbits the Sun, (b) is large enough to be almost round in shape, and (c) is the only large object in its orbit around the Sun. As a result, scientists now explain that the Solar System consists of eight planets: Mercury, Venus, Mars, Earth, Jupiter, Uranus, Saturn, and Neptune. Pluto is no longer a planet! Instead, Pluto is now classified as a dwarf planet.
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Dissertation Examination Committee:
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Committee Member, Dr. E. Michael Nussbaum, Ph.D.
Graduate Faculty Representative, Dr. Kent Crippen, Ph.D.