ABSTRACT

Title of Document: SOURCES OF SELF-EFFICACY IN AN UNDERGRADUATE INTRODUCTORY ASTRONOMY COURSE FOR NON-SCIENCE MAJORS

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The role of the astronomy laboratory on non-science major student self-efficacy is investigated through combining quantitative and qualitative methodologies. The Astronomy Diagnostic Test 2.0 is distributed to an introductory astronomy laboratory for non-science major class in the Spring of 2005. The ADT 2.0 is used to draw comparisons between interview subjects and the remaining class. Eight subjects were interviewed three times throughout the semester in order to determine the important contributing factors to the subjects' self-efficacy beliefs. Results of the quantitative data suggest that the interview participants' general science self-efficacy did not significantly increase over the course of the semester. Results of the quantitative data suggest the most important contributor to the subjects' self-efficacy in the laboratory is verbal persuasion. The results of this limited study suggest that the astronomy laboratory experience is a strong contributor to student self-efficacy beliefs.

SOURCES OF SELF-EFFICACY IN AN UNDERGRADUATE INTRODUCTORY ASTRONOMY COURSE FOR NON-SCIENCE MAJORS

By

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Dedication

I would like to dedicate this paper to all those who have given me a helping hand over the past year and a half. To Oscar, my life, my love: thank you for believing in me when I had lost faith in myself. The extra push you've given me to succeed was exactly what I needed to see myself through this process. To Stephanie: you'll never know how much you've inspired me and made me believe that anything is achievable as long as you have that stick-to-it attitude. Thank you for your support throughout this process. To my roommates: thank you for being the moral support I needed when it all seemed too overwhelming. And last but not least, to Randy. Thank you for giving me the creative license to pursue my curiosity, when others would have forced their own agenda. Your support as an advisor has meant the world to me; without it, I would have given up long ago.

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Chapter 1: Introduction

Science subjects tend to maintain a high profile in popular culture, as evidenced by the common incidence of science topics found in the media. Astronomy is one such science subject that is frequently discussed in the media, whether it is a recent space mission, a celestial happening such as an eclipse or meteor shower, or the discovery of a new black hole. Despite its popularity, most people believe that astronomy is a subject that is not easily understood. This perception is documented in educational literature in the form of student-developed misconceptions or alternative conceptions (Bailey & Slater, 2002; Zeilik, et al., 1998). While many astronomy education studies focus on students' lack of scientific understanding, very few focus on why the misunderstandings developed in the first place. Social cognitive theory provides a possible clue as to why many encounter stumbling blocks to science learning through the construct of self-efficacy.

Self-efficacy is a student's belief in her ability to perform a task (Bandura, 1986). According to Bandura, one of the ways in which an individual obtains self-efficacy information is through direct or authentic experience (1986). In the educational realm, authentic experiences are reached through science laboratory experiences. The science laboratory has long been thought of as an important part of a student's learning experience. Since the inception of the *National Science Education Standards* (*NSES*), the role of the laboratory in the science classroom has become increasingly large due to the emphasis placed on inquiry learning (Hofstein & Lunetta, 2002). The astronomy laboratory provides a unique opportunity to study self-efficacy, as the subject of astronomy tends to spark an initial interest in students, while the laboratory experience provides students with the opportunity to learn about the subject through direct manipulation of materials.

1.1 Purpose

This study was designed to gain an understanding of how students make connections between their laboratory instruction and their self-efficacy beliefs. This was accomplished through an investigation into the aspects of the laboratory environment that affect students the most. While some studies have focused on the role of self-efficacy in the classroom, very few have focused specifically on the role of the science laboratory on self-efficacy (Baldwin, et al, 1999; Dalgety et. al, 2003).

Over the years, many instruments have been developed to measure student self-efficacy (Baldwin, 1999; Smist, 1999), but they rely solely on quantitative collected data, and thus lack the ability to understand the relationship between instruction and self-efficacy beliefs. As result, this study was investigated using both quantitative *and* qualitative data collection and analysis.

Chapter 2: Theoretical framework and research questions

According to social cognitive theory, human functional development evolves through the reciprocal interaction of environmental, cognitive, behavioral, and individual factors (Bandura, 1986). Each factor provides a unique aspect to personal development, and each single factor affects all of the others. This reciprocal interaction between factors results in an arousal of a series of capabilities. Of each of the capabilities a human possesses, none is more influential on academic achievement than self-reflective capability (Bandura, 1986). Self-efficacy, or the perception one has of their ability to perform a task, is a construct of self-reflective thought. Self-efficacy is widely used in academic studies due to its ability to predict academic performance (Bandura, 1996).

2.1 Sources of Self-efficacy Information

There are four ways an individual gathers information about their own self-efficacy. Individuals obtain self-efficacy information through authentic experiences, vicarious experiences, verbal encouragement, and emotional arousal or interest (Alderman, 2003). Events that are experienced firsthand are called authentic experiences. Performances on academic tasks, vicariously witnessing experiences of peers, experiencing encouragement from other individuals, and an emotional state of being that results from an individual's thoughts regarding the completion of a task are all examples of scenarios that add to self-efficacy judgments (Bandura, 1986). Like the factors that contribute to and interact with one another in social cognitive theory, the four sources of information all interact to provide a complete sense of self-efficacy.

2.2 Processes Through which Self-efficacy Works

2.2.1 Cognitive Processes

Self-efficacy influences behavior through the agency of cognitive thought (Bandura, 1993). An individual thinks about their actions long before a task is attempted, during which time the task is evaluated and referenced against self-efficacy beliefs (Bandura, 1993). Attribution theory best explains cognitive influences on self-efficacy (Alderman, 2003). Ability, effort, task difficulty, and luck are the most common attributions that are used to explain outcomes on performances, and thus contribute to behavior (Alderman, 2003).

According to Weiner (as cited in Alderman, 2003), each of these attributions can be assigned to one of three causes: internal/external, stable/unstable, and controllable/uncontrollable. The effect on behavior is dependent upon which of the above labels are assigned to an attribution. For example, ability is viewed as an internal, stable, uncontrollable attribution. Those who attribute poor performance to lack of ability will have lower self-efficacy than those who attribute a poor performance to lack of effort (Alderman, 2003, Bandura, 1986). Those attributions that are considered internal, controllable, and unstable are less likely to have a negative impact on self-efficacy beliefs than those that are external, uncontrollable, and stable (Alderman, 2003).

Attributions, and thus cognitive processes, are influenced through a variety of mechanisms, including direct comparison of one with others (Bandura, 1993).

According to Alderman, direct comparison is used as a means by which individuals make attributional judgments (2003). Direct comparison is important in the academic setting, as the task difficulty is externally controlled by the teacher. As an individual compares their performance to others, they make judgments about their own ability. Attribution judgments are also made through indirect cues (Alderman, 2003). Teachers may inadvertently contribute to negative self-efficacy through their actions. Some of the indirect cues from teachers that have been identified include the amount of praise or blame that is assigned, the amount of expressed sympathy or anger, the amount of unsolicited help that is given, and grouping by ability (Alderman, 2003). These indirect cues are also considered feedback (Bandura, 1993). Attributions that an individual assigns oneself and the resulting self-efficacy beliefs have a direct effect on the amount of motivation that is exhibited.

2.2.2 Motivational Processes

According to Bandura (1993), motivation is driven by self-efficacy beliefs. Along with attribution theory, two other theories are used to explain motivational beliefs. Expectancy-value theory describes the self-efficacy effects on motivation through expected outcomes and their assigned worth, which ultimately determines behavior. Goal theory describes self-efficacy effects on motivation through personal influences (Bandura, 1993). A self-efficacy belief about the ability to achieve a goal determines what goals are set by an individual. Motivation is then affected by the type of goal that is set. If a goal is too high compared to self-efficacy, motivation to achieve that goal will likely be low.

2.2.3 Affective Processes

Emotions induced by a task are controlled through affective processes. Affective processes focus on feelings such as like or dislike. Self-efficacy beliefs about an individual's ability to control the reactions from a task affect which tasks will be attempted (Bandura, 1993). Coping and thought control beliefs are utilized in affective processes (Bandura, 1993). Individuals who are efficacious are more likely to persist on tasks, to control negative thoughts and have better coping strategies, and are less stressed than individuals who are inefficacious. Affective processes in turn have an effect on selection choices.

2.2.4 Selection Processes

Self-efficacy not only determines how individuals attribute their performances, their motivation, and their state of anxiety, it also determines which choices are made about the tasks to be performed. Task selections are made based on perceptions of reactions that are within an individual's ability to cope (Bandura, 1993). Thus, choices about academic paths and career choices are affected by an individual's self-efficacy beliefs. All of the sources of self-efficacy information and processes through which self-efficacy beliefs work mentioned above contribute to academic outcomes described in the next section.

2.3 Effects of Self-efficacy Beliefs on Academic Achievement

Self-efficacy plays an important role in academic achievement. As mentioned previously, when all other factors are controlled, self-efficacy remains the most influential construct to predict academic achievement (Bandura, 1986, 1993, 1996).

Thus, it is important to understand the outcome of self-efficacy beliefs on academic achievement. All four of the processes through which self-efficacy works are affected by the same means of self-efficacy information.

2.3.1 Academic outcomes from high self-efficacy beliefs

The attributions that are assigned to a performance outcome are dependent upon whether the outcome was perceived as a failure or success. Attributions such as the amount of effort, the difficulty of the task, and luck are more likely to be assigned to the outcome when self-efficacy beliefs are high and the outcome of a task was perceived as a failure (Bandura, 1986). Alternatively, a successful outcome is more often attributed to ability (Bandura, 1986, 1993, 1996, 2003). An individual's motivation will be affected depending upon their self-efficacy beliefs. For example, those with high self-efficacy are more motivated, attempt a task longer, will more readily undertake a task, and have a larger array of academic choices available to them than those with low self-efficacy.

2.3.2 Academic outcomes from low self-efficacy beliefs

Research has shown that low self-efficacy can have adverse effects on academic achievement. As a result of failure, those with low self-efficacy attribute their failure to a lack of ability, and since ability is seen as an uncontrollable attribution, a feeling of despair ensues (Alderman, 2003). On the other hand, those with low self-efficacy tend to view an academic success as a result an external, uncontrollable attribution such as of the ease of a task or luck rather than as a result of ability. Repeated failures in an academic setting reduce the likelihood that an individual will persist with their attempts to complete a task in the future (Bandura, 1986). A perceived failure as a result of having an attribution such as lack of ability also tends to lead to performance anxiety and a focus on the negative outcomes of failure (Alderman, 2003). In an effort to save oneself from embarrassment, an individual will avoid those tasks which are perceived as beyond their capabilities, thus limiting their exposure to a variety of academic pursuits (Bandura, 1993).

2.3.3 Outcomes from incorrect self-efficacy judgments

There are many reasons why self-efficacy may be incorrectly judged. Public declaration of self-efficacy judgments could cause an underestimation of skills due to modesty, or an overestimation may be caused by a need to make one look good (Bandura, 1986). Either way, a misjudgment of self-efficacy has consequences on academic performance. Those who underestimate their self-efficacy will avoid tasks that are accomplishable. In this case, learners may not be challenging themselves enough, and underutilizing their skills. On the other hand, an overestimation of self-efficacy leads to an undertaking of a task for which the prerequisite skills are missing. In this case, the most likely outcome is a failure that will result in a new estimation of self-efficacy (Bandura, 1986).

2.4 Relationship of theoretical framework to this study

The science laboratory is an active learning environment in which learners participate in science by interacting with equipment to investigate phenomena. By its very nature, the laboratory provides students with the opportunity to re-construct the meaning of the concepts that are taught in the lecture course. While always considered important in science education (DeBoer, G., 1991), the laboratory has attained an even higher status of importance to science education since the *NSES* emphasized the importance of science as inquiry. When the experience of the science laboratory is compared to the sources of self-efficacy information, many parallels can be seen.

2.4.1 The laboratory as an authentic experience

The publication of the *NSES* in 1996 directed renewed attention on the role of student inquiry in science learning environments. Science as inquiry is a process by which students focus on scientific meaning through the investigation of phenomena, assessment of assumptions, experimentation, and communication (*NSES*, 1996). It is only through such inquiries that students gain a rich understanding of what it means to 'do' science. In their literature review, Hofstein and Lunetta report on many studies that demonstrate the importance of the hands-on experience in learning (2002). Given the hands-on nature of science laboratories, it can only be expected that the science laboratory serves as an authentic experience from which learners can derive self-efficacy information (Freedman, 1997).

2.4.2 The laboratory as a vicarious experience

One of the benefits that has been touted over the years is that students are afforded the opportunity to work cooperatively in the laboratory as opposed to the didactic style of the lecture-based classroom. While the recent push for the student-centered classroom has closed the cooperative gap, the laboratory still far exceeds the classroom in its ability to foster cooperative learning. Hofstein and Lunetta (2002, p. 35) best describe the cooperative learning environment in the laboratory:

> "…the laboratory offers opportunities for productive, cooperative interactions among students and with the teacher that have the potential to promote an especially positive learning environment."

The cooperative learning environment within the science laboratory provides an excellent opportunity for students to gain self-efficacy information through vicarious experiences. Students work in groups, during which time an individual may make observations of her classmates and thus make self-efficacy judgments. Observation of others' performances acts as a model that contributes to self-efficacy information. Bandura states that vicarious experiences are most influential when an individual lacks background knowledge (1986).

2.4.3 The laboratory as a source of verbal feedback

Most laboratory classes are smaller than their lecture-style counterparts, allowing more time for teachers and students to interact. Students receive immediate feedback about progress on their work, as opposed to the lecture-based classroom where feedback mainly comes in the form of progress on an examination. It is through this teacher-student and student-student interaction that students obtain verbal feedback about their laboratory experience. Bandura suggests that the teacher's feedback may be more influential to self-efficacy beliefs than peers due to the credibility that is placed on the teacher (1986).

2.4.4 The laboratory raising emotional awareness

Students working in the laboratory classroom typically work with materials in order to complete their assignments. The hands-on experience of the laboratory may serve as a detriment or an asset to a student's sense of self-efficacy, depending upon the type of reaction that is evoked as a result of the student's participation. Anxiety about handling or understanding the materials may result in lowered self-efficacy, while excitement about handling or understanding the materials may result in raised self-efficacy. It is precisely these interactions that have gone unstudied in science education research. Thus, the first and second research questions address the nature of the laboratory experience and its relationship to self-efficacy.

Research question 1: How do non-major undergraduate students perceive their own astronomy laboratory self-efficacy at the beginning, middle, and end of laboratory instruction?

The second research question was designed to investigate what connections are made between experience and self-efficacy by the students:

Research question 2: What experiences do students identify, and for what reasons, as increasing or decreasing their self-efficacy in the astronomy laboratory?

2.4.5 The effects of the laboratory on attributions

Many learners in the US believe that being good at science is a result of being born with the ability rather than a result of extended effort (Alderman, 2003). As a result, some students only take the minimal number of science classes required to fulfill necessary graduation requirements. In this case, the science laboratory has the ability to influence student attributions, even if learners are unaware of these changed attributions. While students in a lecture-based classroom do not theoretically need to extend any effort in order to learn, participation and hence effort is required for learning in the laboratory classroom. Therefore, students in a laboratory classroom environment may have their attributions affected by simply fulfilling classroom requirements to earn their grade.

Many tasks in the US educational system are either one-time events such as presentations, or are infrequent occurrences such as examinations. As a result, students are either not aware of the difficulty of the task beforehand, or are aware that whatever the difficulty of the task, it will only occur once. Performance judgments based on paper, presentation, or examination results thus lead to science self-efficacy beliefs that are miscalculated. Astronomy laboratories are typically held weekly throughout the course of a semester. The science laboratory has been labeled as important due to its science authenticity (Alderman, 2003). Therefore, it can be argued that self-efficacy judgments based on laboratory experiences are more reflective of a students' science self-efficacy than judgments based on scores on other assignments. The role of the laboratory on student attributions, although a potentially powerful construct, lacks thorough investigation within educational literature. Thus, this study investigated the role of attributions in science laboratory self-efficacy with the third research question:

Research question 3: What attributions do non-major undergraduate astronomy students associate with their perceived self-efficacy? Does this perception change with increased laboratory classroom time?

Chapter 3: Literature Review

3.1 Astronomy Education Research

Although the first astronomy education research articles were published in the early1920s, the proportion of researchers who contribute to astronomy education research is fewer in numbers than those in other educational disciplines (Bailey & Slater, 2003). Nonetheless, those who conduct astronomy education research have generated a large body of information regarding students' conceptions, instructional techniques and practices, and assessment strategies. The recent surge in astronomy educational research publications can be attributed to the inception in 2001 of the *Astronomy Educational Review*, an online publication outlet for those interested in astronomy educational research (Bailey & Slater, 2003). The sheer volume of literature on astronomy educational research prohibits the review of all of the possible topics that could be covered. Hence, this portion of the literature review aims to discuss and summarize the literature that was and has been published around and since the time of Bailey & Slater's 2003 review.

A large majority of the astronomy educational research assumes a constructivist framework, regardless of whether the focus is on age, subject matter, or instructional strategy (Bailey & Slater, 2003). The adoption of the constructivist framework is useful in determining the effect of instructional strategies on student comprehension, but one of the limitations is its ability to make the connection of why instruction affects learning. This limitation is pervasive in the astronomy education research literature, as most of the studies focus only on what students know about astronomy prior to instruction and how that knowledge changes as a result of the assessment, innovation, or instructional strategy of interest.

3.1.1 Research about student understanding – what students know

Much of the literature about astronomy education includes an investigation into what students *know* about astronomy. Of the nineteen articles cited within this section, all but three of them focused on research associated with student understanding. Publication of documents such as the National Research Council's *National Science Education Standards* (*NSES*) (1996), and the American Association for the Advancement of Science's Project 2061: *Benchmarks for Science Literacy* (*Benchmarks)* (1993), have provided guidelines to suggest the amount of content knowledge students should posses at any given age. Astronomy education research mirrors the suggestions of the *NSES* and *Benchmarks* through the analysis of student knowledge by subject and age.

Astronomy educational literature can be divided into two categories with regards to age groups. Some studies use the shotgun approach, studying subjects between kindergarten and university ages in order to gain a broad picture of the state of astronomy understanding (Offerdahl, et al., 2002; Prather et al., 2002). Others studies provide a more focused view, targeting on a small range of ages, including only a single grade, multiple grades, or undergraduate students (Trumper, 2001; Stahly, et al., 1999; Simonelli & Pilachowski, 2003; Zeilik & Morris, 2003; Abell, 2001). Studies that choose to focus on a specific age group incorporate a depth of content that is age-appropriate, although some study results indicate that college students have the same or similar alternative frameworks as elementary students (Kikas, 2004; Trundle et al, 2002).

In her study, Eve Kikas examined the conceptions of teachers on three topics, including the astronomical cause of Earth's seasons (2004). The teachers categorized as 'humanities' were used as the group "…who do not need to know the knowledge of science in their daily work" (Kikas, 2004). Of the subjects in the Kikas study, the humanities teachers most likely typify the average non-science introductory astronomy student. Subjects were given evaluation and performance tasks for each of the three subject categories (Kikas, 2004). The evaluation tasks asked the subjects to evaluate four statements as possible explanations for a scientific concept, while the performance tasks asked the subjects to solve a problem related to a concept and give an explanation for their answers (Kikas, 2004). Only 15% of the teachers could correctly explain the cause of the Earth's seasons (Kikas, 2004).

Questionnaires and surveys are used to collect data on student understanding about both specific and broad astronomy concepts. The most common means of gathering data about students' broad conceptual understanding is through the administration of a multiple choice questionnaire (Deming, 2002; Hufnagel et al, 2000; Trumper, 2000; Zeilik et al., 1998; Zeilik & Morris, 2003). Various instruments have been developed for this purpose, but the most widely used assessment is the Astronomy Diagnostic Test version 2.0 (ADT 2.0) (Deming, 2002; Hufnagel, 2002; Hufnagel et al., 2000; Zeilik et al., 1998; Zeilik et al., 2003). The predecessor to the ADT 2.0 was the ADT version 1 (Zeilik et al., 1998). The ADT 2.0 was developed and tested after the desire for a reliable and valid astronomy assessment for undergraduate non-science majors was expressed by practitioners (Hufnagel, 2002). The validity and reliability of the ADT was called into question upon publication of pilot results, resulting in formation of the ADT National Project (Deming, 2002). The efforts by the researchers involved with the ADT National Project resulted in the participation of 68 professors across 31 states, and the compilation of 5,346 pre- and 3,842 post-course test results (Deming, 2002). Statistical results of the ADT 2.0 suggest high reliability and validity (Deming, 2002).

Researchers interested in students' conceptual understanding of a particular astronomical concept tend to use data collection methods that provide richer data such as interviews, observations and field notes, and open-ended surveys. Concepts that have been investigated using these methods include 'traditional' astronomy concepts such as phases of the Moon, cause of the seasons, shape of the Earth, and gravity (Abell, 2001; Barnett, 2002; Kikas, 2004; Sneider and Ohadi, 1998; Stahly et al., 1999; Trundle et al., 2002). Topics found at the forefront of astronomical research such as cosmology and astrobiology have also been investigated (Miller, 2003; Offerdahl et al., 2002; Prather et al., 2002). In their pilot study, Simonelli and Pilachowski gave their subjects an open-ended survey containing four questions (2003). Their results were inductively analyzed for patterns and 'misconceptions' (Simonelli & Pilachowski, 2003).

3.1.2 Research about instructional strategies – the effect on conceptual understanding

The pervasiveness of students' alternative conceptions about a large number of astronomical concepts is widely recognized in the astronomy educational community.

As a result, many studies have focused on the creation and evaluation of instructional strategies and curricular interventions in an attempt to rectify the problem. These studies cover a broad range of concepts, techniques, and strategies to varying degrees of success. For the sake of brevity, a few studies are provided as examples of the types of research on conceptual change that can be found in the literature. The proceeding studies cover several different avenues of research, including modifying practice through the use of technology, mental model building or reflection, as well as the evaluation of materials used in astronomy courses.

Studies that have focused on the use of technology to promote conceptual change have become more common as technology becomes increasingly accessible to the average classroom. One example of astronomy education research where technology has been completely integrated into the classroom is the study by Barab et al. (2002). In order to determine the effectiveness of technology in the classroom, Barab et al. designed a series of lessons on phases of the Moon using interactive virtual technology software (2002). The main focus of the lessons was to use a three dimensional software package to design a series of models to address a number of 'seed questions' (2002). In order to build their models, students were required to have an elaborate understanding of the motion of celestial bodies, including the Sun-Earth-Moon system. Based on their performance, the professor urged the students to probe deeper into their model through the use of a set of questions. The students were evaluated on their performance through class presentations, group work, and individual papers, all of which were designed to provide interactive feedback with one another (Barab, et al., 2002). As with most of the astronomy education literature, the focus of the Barab et al. research design was to evoke conceptual change within the students, although the depth to which technology was integrated into the change is much greater than with most studies.

Another instructional technique that is commonly used to evoke conceptual change in astronomy education research is the technique of mental model building and/or student reflection. According to Barnett (2002), reflection is a technique that can be used to evoke change even if the alternative conception is not directly addressed. Lessons taught in an advanced science class were designed to have students reflect on their own thinking through the use of journals and in in-class discussions. Students shared their pre-course ideas about the phases of the Moon and eclipses with researchers through interviews. Pre- and post-course interviews indicated that students' conceptual understandings moved toward a more scientific understanding of the phases of the Moon and the cause of eclipses through the treatment (Barnett, 2002). Based on his findings, Barnett suggests that conceptual change can be reached without the confrontation of alternative conceptions that is suggested in previous literature (Barnett, 2002).

Images of the phases of the Moon along with their accompanying text in astronomy textbooks are the focus of Pena and Quilez's 2001 article. They examine the images alone, with the accompanying explanatory text, and the text by itself, to determine whether or not the information provided is sufficient enough to convey the concept to a student such that a student could understand and apply the information. A group of students were also interviewed to determine the effectiveness of the information. Based on their findings, Pena and Quilez conclude that the information found on phases of the Moon in typical astronomy texts is not enough to promote conceptual change (2001). The Pena and Quilez article is yet another demonstration of the astronomy education research on a focus toward conceptual change.

Astronomy education articles are published in a wide variety of journals, from those of interest to the practitioner to those of interest to professional educational researchers. The current concentration on research on conceptual change leaves many possibilities for researchers to engage in concepts of other foci, such as the focus of this research on the role of the astronomy laboratory on self-efficacy. The remainder of this literature review will focus on the research to date on both the role of the science laboratory and self-efficacy in education.

3.2: Science Laboratory Research

The role of the science laboratory in education has been considered an important part of the learning experience for many years. The publication of the *National Science Education Standards* heightened the role of the science laboratory in recent years through the emphasis on learning science as inquiry (Hofstein & Lunetta, 2002). In recent years, the primary focus of educational literature on science laboratories has been on uncovering student epistemologies about the role of the laboratory. Other topics of research on the science laboratory include those that focus on laboratory instructional techniques and on students' science epistemologies, although such research can be considered ancillary to laboratory environment research.

A recent review article has provided insight into the types of research that can be found on science laboratory work. In their review, Hofstein and Lunetta (2002) divide research on science laboratories from the past twenty years into three main categories, including student learning, the role of goals and goal setting in the laboratory, and teacher training and education. The discussion of student attitudes received very little attention as a result of a lack of literature. Since the publication of the 2002 review paper, student attitude has received an increased amount of attention, but only within the realm of student attitudes toward their learning environment. A large portion of the literature that has been published since the Hofstein and Lunetta article have made use of the Science Laboratory Environment Inventory (SLEI), first published by Fraser, McRobbie, and Giddings in 1992.

3.2.1 The Science Laboratory Environment Inventory

The Science Laboratory Environment Inventory (SLEI) was designed as a questionnaire to address students' perceptions of the laboratory environment (Fraser, et al., 1992). The 35-question Likert-scale questionnaire asks students to answer questions about the cohesiveness, open-endedness, integration of theory, rule clarity, and material environment of the laboratory (Fraser et al., 1992). It was recognized that student answers will reflect their perception of the environment rather than the true nature of the environment. As a result of this, Fraser et al. designed two versions of the questionnaire to address students' 'actual' and 'preferred' environments (1992). The purpose behind using two questionnaires is to help the instructor identify the gaps between what students perceive and what students prefer, enabling the instructor to directly address the gaps and make changes to the environment to better suit the student (Fraser, et al., 1992). Recent studies on the science laboratory have made use of the SLEI to address student epistemologies (Henderson, 2000; Tsai, 1999; Tsai, 2003).

The SLEI was used by Tsai (2003) to examine discrepancies in students' actual and preferred laboratory environment as compared to teachers' actual and preferred laboratory environment. Student and teacher actual and preferred laboratory environments were examined through the administration of both versions of the questionnaire. The discrepancies were interpreted as a difference in epistemological views between the teachers and the students. According to Tsai, the results indicate that students tend to have social constructivist epistemologies whereas teachers tend to have positivist epistemologies (Tsai, 2003). Tsai also suggests that the teachers' positivist epistemology is expressed through their desire to portray the laboratory 'aim' as defined by Hart et al., 2000 (Tsai, 2003).

The SLEI is paired with the Questionnaire on Teacher Interaction (QTI) to examine not only the students' actual and preferred laboratory environment, but also student-preferred teacher characteristics in a study by Henderson (2000). The use of both instruments in the study enabled researchers to get a better understanding how student attitudes correlated with achievement. Attitude and achievement were measured using the SLEI, the QTI, and laboratory examination scores (Henderson, 2000). Based on the findings, Henderson argues that higher student achievement is linked to teacher leadership and laboratory open-endedness and cohesiveness with greater clarification of the rules (2000).

3.2.2 Other Laboratory Research

Other science laboratory research has focused on student science epistemologies (Wallace et al., 2003; Wickman, 2003), instructional strategies (Hand, 2004; Hart et al., 2000), and the role of the science laboratory on student attitudes (Dalgety. et al., 2003; Wallace et al., 2003). Studies that focus on epistemology are primarily concerned with students' perception of science. For example, Wickman studied a group of chemistry students during a laboratory examination in order to determine if students made connections between theory and practice (2003). The results indicate that students were only making connections between kinetic theory and their samples after properties of the samples were identified. Wickman's findings were explained through assuming students had positivist science epistemologies, or that science is a series of facts stringed together.

Studies that focus on instructional strategies vary widely in their techniques. Some studies draw on inquiry to develop instructional practices (Wallace et al., 2003), while others use writing as their basis of study (Hand, 2004). Still others focus on the laboratory materials used (Barnett, 2002). Despite the wealth of literature on science laboratories, what has been noticeably missing from the literature has been a focus on self-efficacy in the laboratory. Since Hofstein and Lunetta's review, one article has been published that focuses on student attitude. In their development of the Chemistry Attitudes and Experiences Questionnaire (CAEQ), Dalgety et al include 'chemistry methods' as one of the subscales for the instrument (2003). The authors also borrow items from Baldwin's College Biology Self-Efficacy Instrument (CBSEI) to measure chemistry self-efficacy in the laboratory (Dalgety et al., 2003). While the results of the CAEQ are informative, the instrument was administered to chemistry majors, and thus provides little information about non-science major introductory astronomy students (p. 650).

3.3 Self-Efficacy Research

The construct of self-efficacy was first introduced in 1977 by Albert Bandura. Since then, the construct has been used in education as a mechanism to predict academic behavior. The content of science education literature that uses self-efficacy varies in scope from general, such as linking self-efficacy to academic achievement (Bandura, et al., 1996) to specific, such as developing specific instruments to measure self-efficacy on a specific subject (Baldwin et al., 1999). Self-efficacy has also been linked to other constructs of social cognitive theory, such as attribution theory (Lyden, et al., 2002).

3.3.1 Self-efficacy and academic achievement

The usefulness of self-efficacy as a predictor of academic achievement is supported through a large body of literature both in educational and psychological outlets. Bandura et al. suggest that self-efficacy affects academic behavior through several mechanisms (1996). They present a conceptual model that demonstrates all of the various influences on academic behavior, and through which identify three types, academic, social, and self-regulatory self-efficacy beliefs (1996).

In an article published in 1990, Bouffard-Bouchard demonstrated the role of self-efficacy beliefs on academic performance. In a controlled study, 64 college students were randomly assigned to either a low self-efficacy or high self-efficacy group. Each student was given a set of practice problems, and depending upon their group assignment, was given positive or negative feedback to induce high or low self-efficacy, respectively. The results of the study suggested that those with higher self-efficacy attempted more problems than those with lower self-efficacy (Bouffard-

Bouchard, 1990). The results also supported the hypothesis that those with high self-efficacy are more likely to persist longer than those with low self-efficacy (Bouffard-Bouchard, 1990). The Bouffard-Bouchard lacks the power of understanding self-efficacy sources because it was artificially introduced. Furthermore, Bandura and Locke called into question the viability of artificially induced self-efficacy beliefs (2003). Bandura suggested self-efficacy beliefs vary across time, subject, and setting (1997). The variability in self-efficacy beliefs requires a more detailed examination of the role of self-efficacy in academic performance. More specifically, it is necessary to examine subject-specific self-efficacy beliefs to gain a more accurate view of the role on academic performance.

3.3.2 Self-efficacy and science performance

The variable nature of self-efficacy beliefs inhibits the ability to generalize beliefs across academic subjects. For example, it is highly unlikely that geography self-efficacy will predict how a student will perform in a biology class. Smist and Owen describe the effects of self-efficacy on the enrollment in various subjects and selection career paths (1994). Their discussion supported Bandura's hypothesis of the role of self-efficacy on academic persistence. The Science Self-Efficacy Questionnaire was used to measure biology, chemistry, physics, and laboratory self-efficacy (Smist & Owen, 1994). The results suggested that self-efficacy varied between subjects (Smist & Owen, 1994). The variability between science subjects found in the Smist and Owen article suggest that self-efficacy is science-subject specific.

Chapter 4: Methods

4.1 Overall approach and rationale

Among the most common measures that are used as predictors for student achievement in education research, none has greater predictive capability than self-efficacy (Bandura, 2003). The important influence of self-efficacy on academic achievement has resulted in numerous educational research studies using it as a focus, with most of them using quantitative measures. Most studies in this area have examined the relationship between prior performance and self-efficacy (Lyden, et al., 2002; Speiker & Hinsz, 2004). However, few studies have examined in depth the role of academic performance on self-efficacy. Furthermore, while quantitative measures can give a quick and direct picture of a student's self-efficacy, the factors contributing to their self-efficacy are left unexamined. Only through the application of the qualitative research methodology can an in depth examination occur (Bogdan & Biklen, 2003). Therefore, this study used a combination of quantitative and qualitative methods to provide a more in depth image of the factors that contribute to a students' sense of self-efficacy. Quantitative measures that have already been developed were used to gather information about the class as a whole, while qualitative measures were used to gather information about specific students' self-efficacy.

4.2 Sample Selection

Subjects/participants were chosen from an introductory astronomy course with laboratory for non-science majors at a large public university in the Spring 2005 semester. The Astronomy Diagnostic Test version 2.0 (ADT 2.0) was given at the beginning of the semester by the course instructor, and students were asked to decide whether they were interested in participating in an educational research study for extra credit in the course by the next course meeting. This study was one of two educational research studies being conducted during the Spring '05 semester. Students who were not selected as participants for either study were given the option of completing an out-of-class assignment to earn their extra credit.

Subjects/participants were selected from those students who indicated that they were interested in participating in an educational research study. Of the 154 students who took the ADT, 108 indicated that they were interested in participating in an educational research study. Results from the ADT 2.0 were sorted in order of lowest to highest score, and students with the lowest 21 scores were identified as potential subjects. Student emails were obtained from course information sheets collected by the course instructor, and those identified as potential subjects were contacted via email during the fourth week of classes.

4.3 Quantitative Methods – Instruments

The Astronomy Diagnostic Test (ADT) was developed to provide a valid and reliable assessment tool for those teaching an introductory Astronomy course (Hufnagel, et al., 2000). Based on previous astronomy concept tests, (Zeilik, 1998) questions were selected and answers were developed through a series of student interviews, the ADT 2.0 is a six-page, 33-question multiple choice test (Hufnagel et al, 2000). In addition to 21 astronomy concept questions, the ADT 2.0 asks questions about gender, ethnicity, socio-economic background, prior science achievement, and self-efficacy beliefs. Version 2.0 of the ADT was created after version 1.9 was administered to 1500 students in 17 universities and colleges (Hufnagel, et al., 2000).

The ADT was administered by the instructor during the first and last class meetings. Students were given thirty minutes to complete the test, and answer sheets were collected as the students exited the lecture hall. Results of the ADT were processed using university scantron facilities and results were obtained both in electronic and hard copy form. The electronic copies of the ADT results were used to identify the students who performed in the lowest 20 percent of the class. The administration of the ADT at the end of the semester was used to draw comparisons in knowledge gained for those students selected as participants in this study. Overall class results were used as a statistical comparison between published ADT results and the Spring 2005 Astronomy 101 class. The ADT was distributed at the beginning and end of the semester for two reasons: 1) to serve as a control for prior knowledge and 2) to serve as a control for final achievement or change in initial knowledge.

4.4 Qualitative Methods

4.4.1 Interviews

Three semi-structured interviews were conducted during weeks 5 and 6, 11, and 14 in the Department of Astronomy. The purpose of the interviews was to elucidate deeper information from the participants than could be provided by the ADT. The interviews ranged from 10 to 30 minutes long and were tape recorded and transcribed for evaluation purposes. The complete set of pre-determined questions for each interview is provided in Appendix B.

Interview 1 was conducted during weeks 5 and 6 of the semester. It was during this first interview that the researcher established a repore with the subjects through a description of the researcher's personal background and of the research study. Two types of questions were asked of the participants during the first interview. The first type of question was designed to gather information about the participant's background, while the second type of question was designed to get information regarding the participant's perception of their thoughts and actions when in the laboratory. Follow-up questions were asked depending upon the participant's answers. A semi-structured interview format required that a rigorous set of questions not be adhered to during the interview, although most participants were asked similar follow-up questions that were designed to gather information regarding the participant's views of their own self-efficacy.

The second and third interviews continued with the line of questioning regarding self-efficacy, and required participants to compare their current beliefs with those from the beginning of the semester. Questions such as "Now that you've had some time to adjust to the teaching style/demands of the laboratory, how do you feel about your ability to complete the assignments in the course?" and "How does this compare to how you felt at the beginning of the course?" were asked during the second and third interviews. This line of questioning is directly related to research question number 2: *From the student's perspective, what experiences in the laboratory and for what reasons do students identify as increasing or decreasing their self-efficacy?*

On average, the second interview lasted ten minutes. Students were given a series of open-ended questions, for which most elected to answer with short answers. If the participant responded that their ability stayed the same, questions were asked such as "How do you perceive the amount of effort that you are required to expend to complete the assignments?" or "In your opinion, are you being challenged enough in the laboratory?" Self-efficacy research suggests that the optimal experience for improving self-efficacy requires a success with an experience that was just beyond a person's capabilities (Bandura, 1986).

In addition to questions asking participants to compare their current view of self-efficacy to that of the beginning of the semester, the third interview included questions asking participants to think about what would be changed about the course. The third interview was strategically scheduled during week fourteen of the course in order to provide participants with enough experience to be able to reflect upon what portions of the course specifically added to their current beliefs.

Interviews with the course instructor and teaching assistants (collectively called instructors) were conducted in order to establish an understanding of their instructional style. Semi-structured interviews took place during week 12 of the semester. Each teacher interview was audio taped and transcribed for analysis, and the interview protocol is provided in Appendix C. All of the teachers were interviewed about their instructional style and their perception of their students' confidence. Open-ended questions were used in order to allow each teacher to explain their answers thoroughly.

4.4.2 Task completion activity

Interview data was corroborated through the observation of a predetermined task by each of the interview participants. The task was designed for the students to complete during an additionally scheduled session. The task completion activity was based on a previous laboratory assignment, and students were asked to answer a series of questions based on a scenario. The tasks were designed to allow the student to apply their knowledge to a new situation that was slightly more difficult than was encountered during the laboratory assignment. In this sense, the task completion activity served as a means to triangulate the data gathered during the interviews.

The task took place during week 9 of the semester, and was based on the "phases of the moon" lab that was performed in week 2 of the semester. Participants were asked to answer a set of questions based on the following scenario:

> "Imagine that you are standing on Jupiter's north pole, 5 AUs from the sun, looking at the Earth-Moon system, 1 AU from the sun. Your job, as an astronomer on Jupiter, is to make observations of the Earth and Moon, and describe the positions throughout one Earth year. Assume Jupiter remains at one point in its orbit throughout one Earth year, and answer the following questions. You may use the materials provided to help you with your explanations."

Students were read the scenario, and then asked a series of questions. The protocol of questions for the task is provided in Appendix D. Students were asked to answer questions about the phases of the Earth and Moon, as viewed from the orbit of Jupiter. The questions were designed to require students to apply knowledge learned from the phases of the moon lab and apply them to a more difficult problem. The process of asking a participant to transfer their skills to a new task allowed the researcher to evaluate self-efficacy beliefs in an authentic context, increasing the probability that the participants were expressing their true self-efficacy beliefs and not those contrived in an interview setting. In order to validate the questions for Task 1, the researcher met with the instructors prior to asking them to the subjects, during which time, the questions were modified to reflect those suggestions. The instructors made comments and suggestions about the validity of the questions' scientific merit and level of difficulty.

Observations of the task consisted field notes of the participant's actions, complemented by a tape recorder to record the dialogue between the researcher and participant. Subjects' actions were recorded during the session in the form of "takes Styrofoam ball into left hand, holds it near the light bulb." Field notes and a tape recorder were used in order to minimize the intrusiveness of the observations.

4.5 Data Analysis Procedures

4.5.1 Quantitative data

The quantitative data were combined and analyzed using a statistical analysis package, SPSS. The results of the ADT were summarized and combined to identify trends. Since the ADT 2.0 has been verified through a large population, the results from this study were compared to the existing database to characterize the subjects as compared to the database averages. Therefore, the data from this study were compared to determine if they are similar to previous results. Once identified, subjects who scored in the lowest 20% of the ADT were selected for possible interviews.

4.5.2 Qualitative data

The data that were gathered from the interviews and observations were interpretively analyzed to identify the important factors identified by the subjects. Individual subjects' data were examined to detect any changes throughout the duration of the study. Observational data were analyzed in a similar manner to the interview data. Audiotapes were transcribed and interpretively analyzed. The data from individual subjects were compared to detect changes in self-efficacy during the task completion exercises. Once transcribed and analyzed the observation data were compared to the data from the interviews. Interpretational analysis is the best choice for analysis when the emic perspective is studied (Bogdan & Biklen, 2003). A comparison between quantitative and qualitative sets of data was necessary to distinguish if there were discrepancies between student self-reporting and researcher interpretation.

Chapter 5: Results

5.1 Quantitative Data

The Astronomy Diagnostic Test was administered by the course instructor on the first and last class meetings of the semester. Data were disaggregated and analyzed for several factors, including class pre- and post-course comparisons, subject versus whole class comparisons, and whole class gender comparisons. In all, sixteen statistical tests were performed on the data from the spring 2005 ADT test results. Two types of statistical tests were run on the ADT 2.0 data. Matched pairs statistical tests were run when comparisons between an individual subjects' pre- and post-course scores were made. The matched pairs statistical tests were appropriate in those cases because comparisons were drawn between the same subjects' test results. Independent statistical tests were run when comparisons between gender, and interview subjects and the remaining class were made. In those cases, independent statistical tests were appropriate because comparisons between separate individuals' data were made. A summary of the statistical tests that were run on the data are presented in Table 1. Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 13.0 software. All statistical tests were run at the alpha = 0.05 level as is traditionally accepted for social science research.

t-test for independent means	t-test for dependent means
Male – female pre-course confidence	Spring 2005 pre-post course confidence
Male – female post-course confidence	Spring 2005 pre-post course achievement
Male – female pre-course achievement	Subject pre-post course confidence
Male – female post-course achievement	Subject pre-post course achievement
Subject – class pre-course confidence	Male pre-post course confidence
Subject – class post-course confidence	Male pre-post course achievement
Subject – class pre-course achievement	Female pre-post course confidence
Subject – class post-course achievement	Female pre-post course achievement

Table 1: Summary of statistical tests performed on ADT 2.0 data.

5.1.1 Overall class results

To detect a change in achievement and confidence scores for the entire spring 2005 introductory astronomy class, a t-test for dependent means was conducted. Since the students were given the same pre and post test, a t-test for dependent means was necessary. The data were not used in the statistical test for those individuals for whom one set of scores was missing (either the pre-course or post-course data). The results for the t-test for dependent means for class achievement and confidence are presented in Table 2. The class achievement difference in means was 5.85 with a standard deviation of 3.172, and is statistically significant[1]. The class confidence

[1] Statistical significance is defined as a rejection of the null hypothesis, H_0: $\mu_1 - \mu_2 = 0$, where μ_1 and μ_2 are the means being used for comparison. A failure to reject the null hypothesis does not however,

difference in means is also significant, with a mean difference of 0.882 and a standard deviation of 0.904.

Table 2: t-Test for dependent means for achievement and confidence

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre Score	6.72	120	2.676	.244
	Post Score	12.57	120	3.725	.340
Pair 2	Precon	2.54	119	.842	.077
	Postcon	3.42	119	.786	.072

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Score - Post Score	-5.8	3.17	.29	-6.4	-5.277	-20.2	11	.000
Precon - Postcon	-.88	.90	.08	-1.0	-.718	-10.6	11	.000

Table 2: SPSS t-test results for dependent means for the parameters of class achievement and class confidence. Class achievement and class confidence differences are significant at the $\alpha = 0.05$ level.

5.1.2 Subject results

A total of six tests were run specifically isolating the interview subjects' data from the remaining students. Subjects' pre- and post-course achievement and confidence scores were computed using a t-test for dependent means, as were the remaining class pre- and post-course comparisons. Again, a t-test for dependent means was used because subjects' pre- and post-course results were matched. The results of the

suggest that the differences are not significant. It may imply that the statistical test used was not sensitive enough to detect minute differences.

subjects' pre- and post-course achievement and confidence scores are found in Table 3. There was a significant change in pre- and post-course achievement for both the interview subjects' and remaining class' scores.

Table 3: t-Test for dependent means pre- and post-course achievement and confidence by subject/class

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre Score	3.14	7	.900	.340
	Post Score	9.71	7	3.684	1.392
Pair 2	Precon	2.57	7	.535	.202
	Postcon	2.86	7	.378	.143
Pair 1	Pre Score	6.94	113	2.592	.244
	Post Score	12.74	113	3.671	.345
Pair 2	Precon	2.54	112	.859	.081
	Postcon	3.46	112	.793	.075

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	Upper			
Pair 1 Pre - Post Score	-6.571	3.101	1.172	-9.440	-3.70	-5.60	6	.001
Pair 2 Pre - Postcon	-.286	.488	.184	-.737	.166	-1.54	6	.172
Pair 1 Pre- Post Score	-5.805	3.18	.300	-6.399	-5.212	-19.379	112	.000
Pair 2 Pre - Postcon	-.920	.912	.086	-1.090	-.749	-10.674	111	.000

Table 3: SPSS results for a t-test for dependent means for pre- and post-course achievement and pre- and post-course confidence, with interview subjects separated from the remaining students in the astronomy class. For the interview subjects and class, the pre- and post-course achievement scores are statistically different at with $\alpha = 0.05$. For the interview subjects, the pre- and post-course confidence scores are not statistically different with $\alpha = 0.5$, while the remaining class scores are statistically different at the same α.

The interview subjects' confidence mean difference and standard deviation are 0.286 and 0.488, respectively. These data indicate that there is no statistically significant difference in the interview subjects' confidence between the beginning and end of the semester. In contrast, the class mean difference of 0.920 and standard deviation of .912 is statistically significantly different. These results suggest that while the interview subjects' confidence did not increase, the overall class confidence did.

In addition to the comparisons made between the within-subjects' confidence and achievement scores at the beginning and end of the semester, the interview subjects' pre- and post-course confidence as well as pre- and post-course achievement scores were compared directly to the class' pre- and post-course confidence and achievement results.   Because matched pairs of data were not used for the comparisons between the interview subject and class data, t-tests for independent means were used. The results of the t-tests are located in table 4. The t-test results indicate that the subjects' pre-course achievement mean of 3.38 and standard deviation of 1.061 are statistically different from the class' pre-course achievement mean of 7.03 and standard deviation of 2.674. The test results from the Levene's test for equality of variances was not statistically significant for the pre- and post-course achievement and pre-course confidence tests, thus equal variances were assumed. The Levene's test for equality of variances was statistically significant, however, for the post-course confidence results, thus equal variances could not be assumed. Given the subjects' and class' comparative results for the pre-course achievement test, the statistical difference between the subjects' post-course mean of 9.71 and standard deviation of 3.684 and the class' post-course mean of 12.74 and standard deviation of 3.671 was expected.

The results for the pre-course confidence test between the interview subjects and the remaining class indicate that there is no difference between the subjects' and the class' initial confidence beliefs. The mean and standard deviation for the subjects' pre-course confidence of 2.38 and 0.744, respectively, is not statistically different from the class' pre-course confidence mean of 2.56. The post-course confidence mean for the interview subjects of 2.86 is statistically different from the class' post-course mean of 3.45. These results indicate that there was a larger increase in the confidence of the rest of the class than there was for the interview subjects.

Table 4: t-Test for independent means, subject (rating 3) /class (rating 4) comparison of pre- and post-course achievement and confidence

Group Statistics

	Rating	N	Mean	Std. Deviation	Std. Error Mean
Pre Score	3	8	3.38	1.061	.375
	4	146	7.03	2.674	.221
Post Score	3	7	9.71	3.684	1.392
	4	113	12.74	3.671	.345
Precon	3	8	2.38	.744	.263
	4	145	2.56	.832	.069
Postcon	3	7	2.86	.378	.143
	4	113	3.45	.790	.074

Independent Samples Test

		Levene's Test for quality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	ig. (2-tailed	Mean Difference	Std. Error Difference	Lower	Upper
Pre Score	Equal varianc assumed	3.820	.052	-3.844	152	.000	-3.659	.952	-5.540	-1.778
	Equal varianc not assumed			-8.404	12.651	.000	-3.659	.435	-4.603	-2.716
Post Scor	Equal varianc assumed	.006	.939	-2.118	118	.036	-3.029	1.430	-5.861	-.197
	Equal varianc not assumed			-2.111	6.760	.074	-3.029	1.435	-6.446	.388
Precon	Equal varianc assumed	.360	.549	-.610	151	.543	-.184	.301	-.778	.411
	Equal varianc not assumed			-.675	7.998	.519	-.184	.272	-.811	.444
Postcon	Equal varianc assumed	6.939	.010	-1.969	118	.051	-.594	.302	-1.192	.003
	Equal varianc not assumed			-3.689	9.654	.004	-.594	.161	-.955	-.234

Table 4: SPSS results for the t-test for independent samples for the interview subjects separated from the remainder of the astronomy class. The interview subjects are compared against the class for pre- and post-course achievement scores and pre- and post-course confidence scores. The results indicate that the interview subjects' initial and final achievement scores are statistically different with $\alpha = 0.05$ from the rest of the class. The results also indicate that the interview subjects' confidence scores are not statistically different from the remaining class at the beginning of the semester, but are statistically different with $\alpha = 0.05$.

5.1.3 Gender comparison results

A total of eight statistical tests were run for gender comparisons. Females and males were compared against one another for pre- and post-course achievement as well as pre- and post-course confidence in order to detect any discrepancies in performance. Individual genders were also compared amongst themselves for pre- and post-course achievement as well as confidence in order to detect any within-sample changes in achievement or confidence. The results of the within-gender comparisons are found in Table 5, while the results of the across-gender comparisons are found in Table 6. Males and females both demonstrated an increase in confidence between the pre-course and post-course assessment. The male mean difference is 0.771, while the female difference is 1.041. Both mean increases are statistically significant.

Males and females also demonstrated an increase in achievement between the pre-course and post-course assessments. While both genders demonstrated similar increases in the mean raw score on the ADT, the male mean post-course score of 13.38 was larger than the female mean post-course score of 11.39. The discrepancy in male and female post-course achievement scores, while statistically significant, is most likely a reflection of the discrepancy in pre-course achievement scores, with males and females scoring means of 7.52 and 5.76.

Table 5: t-Test for dependent means pre- and post-course confidence and achievement within gender

Paired Samples Statistics

Gender			Mean	N	Std. Deviation	Std. Error Mean
1	Pair 1	Precon	2.27	49	.785	.112
		Postcon	3.31	49	.769	.110
2	Pair 1	Precon	2.73	70	.833	.100
		Postcon	3.50	70	.794	.095

Paired Samples Test

Gender			Paired Differences					t	df	Sig. (2-tailed)
			Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
						Lower	Upper			
1	Pair 1	Pre - Postcon	-1.041	1.020	.146	-1.33	-.748	-7.14	48	.000
2	Pair 1	Pre - Postcon	-.771	.802	.096	-.963	-.580	-8.05	69	.000

Paired Samples Statistics

Gender			Mean	N	Std. Deviation	Std. Error Mean
1	Pair 1	Pre Score	5.65	49	2.156	.308
		Post Score	11.39	49	3.415	.488
2	Pair 1	Pre Score	7.45	71	2.766	.328
		Post Score	13.38	71	3.735	.443

Paired Samples Test

Gender		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
1	Pre - Post Score	-5.735	3.187	.455	-6.650	-4.819	-12.59	48	.000
2	Pre - Post Score	-5.930	3.182	.378	-6.683	-5.176	-15.70	70	.000

Table 5: SPSS results for t-test for dependent means comparisons within gender for pre- and post-course confidence and achievement. Males and females demonstrated a significant increase in achievement and confidence scores between the pre-course and post-course assessments. All test results are significant with $\alpha = 0.05$.

scores suggested that equal variances between males and females cannot be assumed, since the test was significant. The results of the pre-course confidence scores indicate that the female mean of 2.27 is statistically significantly different from the male mean of 2.72; however, the statistical difference is not indicated in the post-course confidence results, as they are not statistically significant. The Levene's test for equality of variances for both cases (the pre- and post-course results for confidence) is not significant, suggesting equal variances can be assumed.

Table 6: t-Test for independent means pre- and post-course achievement and confidence comparisons across gender

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Pre Score	1	59	5.76	2.046	.266
	2	95	7.52	2.902	.298
Post Score	1	49	11.39	3.415	.488
	2	71	13.38	3.735	.443

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Pre Score	Equal variances assumed	6.805	.010	-4.054	152	.000	-1.753	.432	-2.607	-.899
	Equal variances not assumed			-4.389	149.499	.000	-1.753	.399	-2.542	-.964
Post Score	Equal variances assumed	1.792	.183	-2.973	118	.004	-1.993	.670	-3.320	-.665
	Equal variances not assumed			-3.023	109.032	.003	-1.993	.659	-3.299	-.686

Group Statistics

	Gender	N	Mean	Std. Deviation	Std. Error Mean
Precon	1	59	2.27	.762	.099
	2	94	2.72	.822	.085
Postcon	1	49	3.31	.769	.110
	2	71	3.49	.791	.094

Independent Samples Test

		Levene's Test f Equality of Varia		t-test for Equality of Means						
									95% Confidenc Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Differenc	Lower	Upper
Precon	Equal variances assumed	1.151	.285	-3.40	151	.001	-.452	.133	-.715	-.190
	Equal variances not assumed			-3.46	130.31	.001	-.452	.130	-.710	-.194
Postcon	Equal variances assumed	.390	.533	-1.28	118	.201	-.187	.145	-.474	.101
	Equal variances not assumed			-1.29	105.15	.199	-.187	.145	-.473	.100

Table 6: SPSS results for t-test for independent mean comparisons across gender for pre- and post-course achievement and pre- and post-course confidence. Both the pre- and post-course assessments for achievement suggested a statistically significant

difference between male and female performance with $\alpha = 0.05$. However, the statistically significant difference in confidence between genders that was demonstrated in the pre-course assessment was not apparent in the post-course confidence assessment.

5.2 Qualitative Data

5.2.1 Course description

The introductory astronomy course that was examined in this study met twice a week for one hour and fifteen minutes. A total of one hundred fifty five students were enrolled in the spring 2005 semester. Along with the lecture period, there were separate times allotted for laboratory and discussion classroom time. Students enrolled in one of eight different laboratory meeting times, and all but two of the eight reached a maximum capacity of twenty students. The laboratory classes were scheduled in blocks of two hours, and the discussion sections in fifty minute intervals. An instructor, Ms. Smith, taught the lecture portion of the introductory class, and the laboratory portions were taught by one of four teaching assistants. Pseudonyms are used for all participants in this study.

The instructor was asked to describe a typical day in the astronomy lecture. The lecture began with a sky watch activity, which encourage students to make observations of celestial happenings or think about an astronomical concept. Following the sky watch, the instructor reviewed material from the previous lecture. Often, but not on a daily basis, the review was followed by a demonstration about the forthcoming lecture material. One of the major points that was stressed by the instructor is that it was important for her to get her students engaged in the lecture material. As a result, Ms. Smith used cooperative learning in the lecture. While a standard lecture is unavoidable with a large class, the instructor was very cognizant of getting her students involved in the learning process.

The format for all eight of the laboratory sections was the same, regardless of who taught them. The students were given a lecture during the first ten to fifteen minutes of the laboratory class, which consisted of a review of the scientific concept covered in the laboratory assignment, as well as a preview of the lab. The students completed their laboratory assignments with the remaining class time. During this time, the teaching assistants were available to help the students with questions or difficulties they might have with the assignment. Most of the laboratory assignments were individual, meaning that students were required to complete the assignment on their own. However, students were encouraged to help one another with any questions they might have regarding the assignment. Several assignments required students to work with partners, where each partner was required to make data measurements and collaborate on the interpretation. The amount of in-depth interaction between the students and teaching assistants varied depending upon the teaching assistant, however all four of the teaching assistants indicated that they spent the entire class time interacting with students.

5.2.2 Instructor and Teaching Assistant Interviews

The instructor and teaching assistants were interviewed once during the semester. The purpose of those interviews was to learn about the classroom structure, as well as to learn about the individual teaching and learning philosophies of the teachers. The instructor was asked a series of questions similar to the teaching assistants, but due to the greater interactive nature of the laboratory environment, the teaching assistants were asked about their student interaction in greater depth. The following are the results of those interviews.

Ms. Smith is a White female, who had been teaching the introductory astronomy laboratory course since its inception thirteen years ago. Prior to teaching the introductory astronomy course, Ms. Smith had taught two years of eighth grade science and mathematics. In addition to the introductory astronomy course, Ms. Smith had experience teaching all of the junior-level astronomy courses with the same university. Ms. Smith also developed and taught one of the sophomore level astronomy courses. Ms. Smith also participated in professional development, teaching two courses geared toward teachers.

Regarding her teaching style, Ms. Smith describes herself as "fun." To make her course interesting to her students, Ms. Smith incorporates a variety of teaching tools in her lectures. Overheads, PowerPoint slides, demonstrations, media clips, and cooperative learning techniques are all used in order to keep the students engaged in the learning process. Ms. Smith ascribes to the constructivist learning philosophy, often referring to her students as holding "misconceptions" about astronomy topics. According to constructivist theory, students enter the classroom with prior beliefs about a particular concept that is not the accepted scientific understanding. In order for a student to change their belief, their idea or misconception must be confronted and changed through instruction (Posner et. al, 1982). For example, when she discusses the use of the "think-pair-share" method in the course, Ms. Smith claims that it "is very important in confronting the misconception and… correcting it." Ms. Smith indicated that she did not have much interaction with her students outside of the lecture. While she often greets students in non-academic situations, Ms. Smith said that very few students come to her office hours. Reacting to this interaction, Ms. Smith said that it “is a real lacking,” and that “they’re much more comfortable with the TAs and they tend to go the TAs.”

Ms. Smith has pre-conceived notions about the students enrolled in her astronomy course. According to Ms. Smith the students, “for whatever reason don’t like science.” Ms. Smith also spoke about her students’ self-efficacy when she said, “I think they are pleasantly surprised with what they can do if they give it a chance.” Her comments suggest that Ms. Smith believes that her students’ self-efficacy improves, specifically saying, “I would like to think that the confidence grows.” When she was asked about her teaching abilities, Ms. Smith responded that she had very high confidence in herself. According to her, Ms. Smith rates herself as “above average to exceptional.” Further elaboration of her responses suggests that Ms. Smith is basing her high self-efficacy on her student evaluations.

As mentioned above, due to the greater interaction the teaching assistants had with the students, the interviews for the teaching assistants were slightly different than the interview for Ms. Smith. In addition to questions asking about their teaching experience, the teaching assistants were asked to estimate the amount of time their students remained engaged in the laboratory activities. The teaching assistants were also asked questions regarding their perception of their students’ confidence in the laboratory class. These questions were asked in order to gain a perspective other than those of the subjects’.

Mary is a first-year graduate student in the Department of Astronomy at the university, who had no prior teaching experience outside of the introductory astronomy course. Mary began teaching the introductory astronomy course in the Fall of 2004, which made the spring section of the course her second semester teaching. The typical laboratory session is similar for Mary as it is for the rest of the teaching assistants. The first ten to fifteen minutes of the laboratory section are spent with Mary lecturing and making notes on the chalkboard and discussing the assignment for the day. Mary spends the rest of her laboratory time circulating around the classroom answering her students' questions. According to Mary, her students finish their assignments "quickly," usually within an hour to an hour and half after the laboratory began.

Mary used scaffolding techniques to help her students with their questions. She referred to diagrams and hypothetical situations in order to get her students to think about the question in greater depth, rather than just give her students the answers outright. Regarding her beliefs about her students, Mary labeled her class as "smart," and places them in the top half of the standings in the overall astronomy class. Mary described her relationship with her students as "really good." When she was asked if she knew her students' names, Mary responded with a resounding "Yes." Mary then elaborated and said, "I feel like we can chat about stuff outside of class, and I think I'm pretty personable." Mary's response indicated that she feels comfortable with her students.

Mary indicated that she perceives her students as feeling confident with the purpose of the laboratory assignments. However, she also indicated her students' lacked confidence in their scientific interpretations. Mary also indicated that are a few students who rely on her more than the rest of the class. According to Mary, these students "look for me to for reassurance… they like to check with me." Similarly, Mary believed that her students would only be about sixty percent confident about completing the laboratory assignments on their own. Mary's perception was drawn from her experience with her students' questions. When she was asked about how many questions she receives in a typical laboratory session, Mary replied, "on the harder labs, like non-stop. On the easier ones… they usually ask one or two starting questions and go off on their own."

Despite Mary's lack of prior teaching experience, she described her teaching self-efficacy as fair. Mary was hesitant at first to rate her own teaching abilities. When she was asked, Mary replied, "I can't do that." When nudged to give a response, Mary responded that she was more confident in a one-on-one situation than she was with a large group. Mary's one-on-one teaching self-efficacy was supported when she responded to the question regarding her confidence in explaining a concept to a student and having the student understand it, "Like 90%." Even though Mary claimed that she was not confident when teaching in front of a group, Mary said during the interview, "I think I do a good job in the beginning… describing what's going on or what are we doing."

Tianhuan is a second-year graduate student in the astronomy department at the university. Besides her two semesters of teaching the introductory astronomy course with the laboratory, Tianhuan taught two semesters of the introductory astronomy course without the laboratory. Unlike most of the other teaching assistants, Tianhuan spent an average of a half an hour giving instructions about the laboratory assignment at the beginning of each laboratory session. The remaining time in the laboratory sessions was devoted to allowing the students to complete the laboratory assignment. Similar to Mary, Tianhuan expressed that her students were anxious to complete the laboratory assignment and leave the classroom; the lecture plus the completion of the assignment only took between an hour to an hour and a half.

Tianhuan's teaching style is reflected in her desire to have her students understand the course material. According to Tianhuan, she "want(s) them to understand the material, like something pretty close or relevant to the lecture stuff." For her lectures, Tianhuan used transparencies rather than the chalkboard. When she discussed her teaching philosophy, Tianhuan said that she "wants to lead them to the right answer," but finds that she sometimes had difficulty explaining herself because of a language barrier (Tianhuan's native language is Chinese). Tianhuan spoke of being "nervous" the first time she taught the introductory astronomy laboratory, but now finds that she's "feeling more comfortable and more familiar with the material."

Tianhuan claims to have a good relationship with her students. When she was asked if she knows her students' names, Tianhuan replied, "I know them all." Similarly, Tianhuan spoke of "making friends" with her students. Tianhuan said that she does not see many of her students during her office hours, and that most of her interaction with her students was during regularly scheduled class times.

When she was asked about her students' confidence in the laboratory, Tianhuan replied, "Most of them are confident." Tianhuan then described two students out of each of her sections that are "not very confident," based on the idea that they “are always the last two, uh left in the lab, and they ask like more questions and I have to spend more time with them.” The perception that Tianhuan held about her students’ confidence in the laboratory was not carried over to their ability to understand the purpose of the laboratory assignments, as Tianhuan claimed that she was not “optimistic”. Tianhuan’s statement, “sometimes it makes me feel bad if they don’t understand the purpose, they only want to know, you know, how to do it,” suggests that her students are not engaged in the concepts of the laboratory assignment, but are more interested in finishing quickly.

Based on her responses to the interview, Tianhuan has indicated that she has high teaching self-efficacy. When she was asked to evaluate her teaching abilities, Tianhuan rated herself a “B” or a “B +.” This rating was given, Tianhuan explained, because she sometimes has difficulty expressing herself, and if it were not for the language barriers she encounters, she would rate herself higher. Similar ideas where expressed when Tianhuan was asked about her confidence in being able to explain a concept to one of her students and have that student understand it completely. Tianhuan responded, “I think for most, um, the concepts in (the class)… I can handle it.” Tianhuan recognized that she puts forth effort in her teaching.

Like Tianhuan, Melanie was a second year graduate student in the Department of Astronomy at the university. Melanie was the most experienced teaching assistants of the four. In addition to tutoring, Melanie had experience teaching three semesters of undergraduate physics laboratories, and was in the middle of teaching her fifth semester of the introductory astronomy laboratory course. For her lectures, Melanie used overhead transparencies and student handouts. According to Melanie, her strategy was to give students handouts with some of the lecture information missing, so that the students were required to pay attention to learn all of the material. Similar to the other teaching assistants, her lecture lasted between twenty and thirty minutes, with another hour and a half for the students to complete the laboratory assignments.

Melanie's teaching style is best described as direct, as she takes a no-nonsense approach to her teaching. There were several instances where Melanie described explaining a concept until students "get it." When it comes to learning philosophies, Melanie describes the reason why she allows her students to work together, "I think it's good to hear it in another students' voice as well, like besides just mine." Melanie recognizes the important role a student has in her own understanding. According to Melanie, one of the most frustrating things for her when it comes to teaching is, "not being able to help some of the students because they are not helping themselves." Melanie's learning philosophy is also apparent when she says, "you can't go to their dorm room at teach it to them."

Melanie has some of the same perceptions about her students' attitudes as some of the other teaching assistants. Melanie discusses the idea that her students "want to get out of there" as soon as possible, so they do not spend a lot of time on off-task activities. Melanie also seems to have a good relationship with her students. As with the other teaching assistants, Melanie knows all of her students' names, and says, "we're all friends." When Melanie answered questions regarding her students' confidence in the laboratory, Melanie's perceptions and teaching self-efficacy became obvious. Melanie says that her students "understand it well when I'm done talking about it to them," and that she thinks "by the time they're done they understand why they were there."

It is impossible to know whether Melanie's perceptions of her students' confidence are skewed by her own teaching self-efficacy, or whether she is viewing her students' confidence with an unbiased eye, especially when she discusses her students' confidence in summarizing the purpose of a laboratory assignment. Melanie's response to the question was that her students would only be about fifty percent confident in summarizing the purpose of a laboratory assignment. However, Melanie explains the low number by noting, "I think the book is poorly written and I think there's a lot of stuff that is just incredibly tedious for no reason at all." Melanie's teaching self-efficacy is further supported when she said that she would be 95% confident that she could explain a concept to a student and have that student understand it completely.

Sean was a first year graduate student in the Department of Astronomy at the university at the time this study was conducted. Like Mary and Tianhuan, Sean was in the middle of his second semester teaching the introductory astronomy laboratory course. Outside of his laboratory teaching, Sean previously taught two semesters of college level calculus classes. Sean incorporated transparencies as well as the use of the whiteboard in his lectures. At the beginning of his laboratory class, Sean gives a ten to fifteen minute lecture that consisted of a description of the relevant book readings and the laboratory procedures of the day. Following the lecture, the students took between and hour and fifteen minutes to an hour and a half to complete the laboratory assignment. Sean also interpreted the amount of time that the students took to complete the assignment as a sign that the students wanted “to get out of there.”

When he was asked to describe his teaching style, Sean responded, “I try to be pretty straightforward.” Throughout the interview, Sean’s philosophy about teaching was apparent. For example, even though he knew some of his students were frustrated with him, Sean tried not to “give answers” away, but wanted his students to figure the answers for themselves. Sean also claims that his teaching philosophy is “different from some of the other TAs.” The teaching philosophy to which Sean ascribes himself is similar to how he views learning. On several occasions, Sean described having “bright” or “hardworking,” students as the ones who “get it.” Based on his beliefs, if the student is smart or hard working enough, his indirect answers to student questions will lead a student to the “right answer” on a question.

Sean describes his relationship with his students as “friendly,” saying that his students “joke around” with him a lot. He also describes himself as having a “good repore” with most of his students. Like all of the other teaching assistants, Sean knows each of his students’ names. When he was asked about his students’ confidence in the laboratory, Sean responded by saying that his “smart” students are confident, but that some students have “to have everything handed to them,” and those students would be less confident. Similarly, Sean attributes his rating of his students’ confidence in summarizing the purpose of the laboratory to his introductory lecture. According to Sean, his students would not be confident in explaining a laboratory assignment’s purpose if it were not explained to them.

The responses Sean gave to his perception of his students' confidence suggest that he has at least moderate teaching self-efficacy, which is supported when he describes his teaching ability as average. The estimate that Sean gives about his teaching ability, he says, is based on the idea that "I seem to have average students and they're doing averagely." When he was asked in his confidence in his ability to explain a concept to a student and have him understand it completely, Sean responds by saying "given you know, a reasonably large amount of time, I'm fairly confident that I can do it." Sean's response to that question also seems to support his teaching self-efficacy beliefs.

5.2.3 Participant Interviews

1. Rebecca

Rebecca was a nineteen year old White female. She was in her second semester of her freshman year when the interview took place. Rebecca had taken four science classes in high school, all of which had a laboratory component associated with them. The term "laboratory component" is defined as any assignment, activity, or demonstration where the student is required to use a set of laboratory skills or interact with laboratory materials.

Like most of the subjects of this study, Rebecca indicated that she had low self-efficacy beliefs about her science abilities. The first interview with her provided an understanding of the source of Rebecca's self-efficacy beliefs. Rebecca indicated that she "loved" her classes in elementary and middle school, and she had an acute interest in her forensics class in high school and therefore enjoyed it. Rebecca's low self-efficacy started with her chemistry class. Rebecca's chemistry teacher began instilling the notion of chemistry abilities through the use of ability grouping in the classroom. Rebecca recalls being placed in groups according to their chemistry performance. It was through this "ability matching" that Rebecca became aware of the levels of understanding amongst herself and her classmates. When asked about her feelings regarding this practice, Rebecca replied that "it was… kinda hurtful" but that she thought that "it makes sense." It seems as though Rebecca was very susceptible to comparisons between herself and her classmates. In her forensics class, Rebecca recalled being "at the top of my class," and her self-efficacy about that class seemed to reflect her position.

Rebecca recalls having trouble with her chemistry class, requiring a tutor to help her with the course material. A one-on-one encounter with her chemistry teacher further hindered Rebecca's self-efficacy. Rebecca recalls an incident between herself and her chemistry teacher where she was told "that I was a B student and I couldn't get anything above a B in science." Her self-efficacy was further decimated when the chemistry teacher "really discouraged me from taking upper level physics" and told her "…I wouldn't do well in it." Rebecca recalls having this encounter with her chemistry teacher be "the point" where she lost her confidence in science. Further interviewing revealed that Rebecca had trouble with her other high school science classes following her chemistry class. Rebecca's description of her high school science experience revealed behaviors consistent with those with low self-efficacy. For example, Rebecca recalls having difficulty with her physics teacher, as she placed blame on her struggles in physics with her teacher's inability to teach physics. Rebecca describes her physics teacher as "utterly ridiculous," a "fool," "horrible," and that he “didn’t know what he was doing.” This description is mirrored when she describes her biology and forensics teachers. According to Rebecca, her biology teacher was “a mess,” and her forensics teacher “wasn’t… a challenging teacher.” The description of her forensics teacher is worth noting, considering that Rebecca recalls having performed well in her forensics class. Despite her good performance, Rebecca attributes her success to the difficulty of the class rather than to her own credit. The behavior of attributing a success to an external, uncontrollable event is typical for those with low self-efficacy.

Rebecca’s low science self-efficacy is apparent in the first interview. Her beliefs in science understanding as an ability are apparent through statements such as “people…at your level,” calling others “science geniuses,” and saying that she wanted to work with someone who “was a little smarter.” Rebecca described avoidant behavior, as she chose a class that she perceived as being “easier” than the other science classes in which to enroll to fulfill her college science class requirements. In addition, Rebecca said that she was anxious about taking the astronomy class, and that she was “unhappy” about having to take a science class at all.

Evidence of Rebecca’s self-efficacy also became apparent when she spoke about her behavior inside the laboratory classroom. The most influential contributors to Rebecca’s self-efficacy were that of vicarious experience and verbal encouragement. The first interview exposed several instances of vicarious experiences where Rebecca’s self-efficacy was apparent. During one of the first laboratory assignments, Rebecca partnered with a student whom she considered having less understanding in the class than she. Rebecca described the experience as "frustrating" when it was up to her to provide the understanding and knowledge necessary to successfully complete the laboratory assignment. As a result, Rebecca said that her partner "brought me down a little bit," and that she knew next time to work with someone who was "smarter" or "seemed to… understand what they were doing better" than her previous partner. Once she changed partners, Rebecca expressed feeling more confident in her understanding. Further evidence suggests that Rebecca relies on the vicarious experience for her self-efficacy beliefs when she discussed working individually on laboratory assignments. "I do get nervous when it's individual activities because… I like to really be sure that I'm getting the right answers and doing it right." This statement suggested that Rebecca is not confident enough in her own abilities to be sure that she understands the material.

Rebecca's reliance on verbal encouragement is exposed when she discusses her interactions with her teaching assistant. The following is an excerpt from the first interview:

> "…sometimes I feel like when I ask the TA questions you know, I knew that's what they're there for, sometimes I feel like I'm stupid or the TA thinks I'm stupid. I don't like it (February 23, 2005)."

As a result of these thoughts, Rebecca minimized her interaction with her teaching assistant. Her beliefs about her teaching assistant's thoughts are most likely a result of her prior negative experience with her chemistry teachers. Thus, Rebecca inhibits her own verbal persuasion source of self-efficacy.

The authentic experience of the laboratory environment plays an important, albeit a lesser role in Rebecca's self-efficacy. When asked what role the laboratory environment played in her confidence in astronomy, Rebecca responded that it has decreased her confidence. Rebecca views the laboratory environment as an experience that reminds her of her self-perceived astronomy deficiencies. In her responses to her laboratory experience, Rebecca made statements such as “it’s a realization like what you understand, what you don’t,” and “Oh my god I’m so stupid I can’t get this.” While the laboratory experience seemed to decrease Rebecca’s self-efficacy in some ways, it also seemed to help in others. Rebecca stated that seeing things “hands-on” helped her understand some of the concepts. Likewise, Rebecca claimed “it helped us understand it more when you’re able to see it.” Visualization of the concept helped increase Rebecca’s understanding.

The second interview afforded the opportunity to see how or if Rebecca’s self-efficacy views had changed since our previous meeting. At the beginning of the interview, Rebecca stated that she was starting to feel more comfortable with the laboratory assignments. Similar to the first interview, Rebecca described vicarious experiences, verbal persuasion, and authentic experiences as the most influential in shaping her self-efficacy. However, upon further examination, it was revealed that vicarious experiences play an increasingly larger role in Rebecca’s self-efficacy.

Vicarious experiences for Rebecca included observing classmates’ performance in the classroom, interactions with peers whom she considers on the same ‘level’ of understanding as herself, and asking questions of her peers. Rebecca stated that individual assignments make her “nervous,” suggesting that she was still hesitant to rely on her own understanding to make it through the assignment. Similarly, Rebecca stated, “I like the security of the classroom,” suggesting that she relied heavily on her peers to help her with the assignments. When she was asked if her confidence had changed since the last time we spoke, Rebecca responded by saying "I think I'm less confident," and continued on to compare her performance in the class with that of her brother's, who took the class prior to her enrollment.

Rebecca described a situation where she was separated from her partner to work on a laboratory assignment when she was asked to describe an experience that caused her anxiety. Each partner was to complete part of the assignment and then work together in order to compare data and finish the laboratory assignment. Rebecca describes having the "harder" portion of the assignment, and stated that she "was really stressed out" about having to complete the assignment. Again, comparisons were drawn between Rebecca and her classmates when she stated "we were like the last two people left in the class." Rebecca spoke of "holding her partner up" and feeling poorly about it. In the previous situation, Rebecca was using the comparison of the amount of time it takes to complete the assignment as a testament to her lack of understanding in the classroom.

The relationship that Rebecca had expressed with her teaching assistant in the first interview did not seem to change in the second. Rebecca expressed her concern over appearing like she was "stupid" when she interacted with her teaching assistant. From what Rebecca described, verbal persuasion seemed to be lacking between her and the authoritative figure. Rebecca described her teaching assistant as "unapproachable," and compared her understanding to his. However, Rebecca's anxiety about her relationship with her teaching assistant was alleviated when she interacted with another teaching assistant. Due to class conflict, Rebecca's teaching assistant was required to leave the classroom toward the end of the class period and a second teaching assistant joined Rebecca's class. Rebecca described her relationship with her second teaching assistant as much more amenable, stating "she's much, much more helpful and willing…" and "…really wants to help us," and that "…she makes me feel better." While Rebecca was not getting the verbal persuasion from her main teaching assistant, it seemed that she is receiving encouragement from the secondary teaching assistant.

Rebecca's attributions seemed to change slightly from the first interview to the second. While during the first interview Rebecca attributed her self-efficacy beliefs to ability, the difficulty of the course, and the teaching assistant's ability, during the second she placed a greater emphasis on ability, less emphasis on the difficulty of the course, and expressed a new attribution of prior knowledge and experience. When Rebecca was asked about the amount of effort that she was exerting toward the class, she indicated that she was exerting a lot of effort to her astronomy class, to the detriment of her other classes. Rebecca's attribution shift is demonstrated in the statement:

> "But I thought if I worked really hard, you know, asked questions, and studied really hard I'd be fine. I mean, I do all of that, and I'm not getting as good grades as I would like…(April 18, 2005)."

Prior to making the above statement, Rebecca commented on her perceived abilities compared to that of her brother's. The juxtaposition of the two statements suggested that Rebecca attributed science understanding to ability rather than effort and felt *justified* in doing so. While Rebecca stated that she found some portion of the assignments challenging, she also de-emphasized the difficulty of the class when she said she "had more trouble with" the laboratory assignments at the beginning of the semester.

The familiarity Rebecca had with the course material during the second interview enabled her to speak about the role that prior knowledge had in her selection of the course as her science requirement. In a sense, Rebecca's prior knowledge was not directly attributed to her self-efficacy, but *indirectly* in the choices she made for her science course. Rebecca spoke about other courses she had familiarity with, such as physics, chemistry, and biology, and knowing the difficulty she had in the past with the courses, she chose a course that she perceived as easier. Having little prior experience with the subject of astronomy, Rebecca was unaware of the expectations that would be required of her in the course. Based on her self-efficacy beliefs, Rebecca avoided what she perceived as a harder science class in exchange for one that she was told would be easier. With the experience of half a semester of astronomy under her belt, Rebecca stated that if given the choice, she would not again enroll in the astronomy class.

Rebecca was asked to recount if her confidence in astronomy had changed over the semester. Interestingly, Rebecca recognized that her self-efficacy had changed, describing how her confidence grew with the course of the semester (i.e. familiarity with the course material), but not to the point where she was before the first astronomy class meeting. Despite her original claim that she was more confident than she had been previously, Rebecca made a statement toward the end of the interview that suggested otherwise. When discussing whether the laboratory affected her opinion of her science ability, Rebecca claimed that she leaves class thinking that the material that was covered added to the burden of material she was required to learn. Rebecca specifically stated, "one more thing for me to have trouble learning or remembering," suggesting that her self-efficacy did not improve as much as she claimed. Rebecca stated that she was at least confident enough to be able to complete her course assignments on her own, with the "crutch" of having someone to discuss the assignment. Vicarious experience again played a role in contributing to Rebecca's self-efficacy. In fact, Rebecca rated the importance of working with a partner an "8" on a scale of 1 to 10, with one being the least important and ten being the most important.

While Rebecca stressed the importance of the vicarious experience in her astronomy experience, the nature of that experience shifted with the change in her self-efficacy. Prior experiences for Rebecca included those that seemed to confirm her low self-efficacy, such as when she observed other students finishing the assignment before her. However, Rebecca changed the description of her laboratory experiences in the third interview. Rebecca described working with her classmates as "equal" and spoke of "pulling her partner up" when they had less understanding than she. Similarly, Rebecca spoke to the importance of having partners, but recognized that she would not "want to be stuck with a bad partner." As in the previous two interviews, Rebecca discussed the role of the authentic experience in the astronomy laboratory classroom. It seems as though having "hands-on" activities was essential for Rebecca to understand certain concepts.

Prior knowledge was also addressed in the third interview as it was in the second. Familiarity with the course structure played a part in Rebecca's self-efficacy beliefs. Rebecca discussed whether or not she would take the astronomy laboratory class again, and again stated that she would not, if given the choice, re-take the class. The reasons for this, however, were different than in the second interview. Rebecca talked about how the laboratory class forced her to confront her level of understanding in the astronomy class, but she also discussed how she believed the two components of the class – the lecture and the laboratory – are two different classes. Here Rebecca's "prior knowledge" took the form of her familiarity with the course expectations as well as content.

Conversation during the task was limited with Rebecca, although some information was gathered at the beginning of the session. When asked how well she remembered the materials, Rebecca replied that she did not remember them well. Her confidence in answering the questions was very low throughout the session. The particular material that was covered, in Rebecca's words, "something that I had a little bit of trouble grasping." Throughout the session, Rebecca seemed hesitant to answer the questions. Rebecca's actions seemed to support her responses in the interviews, that she was not confident in her astronomy abilities, and that she relied heavily on the support from others to help her with the assignments. Prompts such as "you may use the materials provided," were given in an attempt to get Rebecca to think through the questions that were being asked of her. Despite these prompts, Rebecca made no motion to think through the questions before she answered. In order to make it easier, the materials that were provided were manipulated for her in order to help Rebecca visualize the concepts.

Although Rebecca claimed that having "hands-on" experiences helped her understand the material, the encounter during the task suggested otherwise. The task was picked specifically to provide materials with which the subjects could work, but the materials merely seemed to intimidate rather than help Rebecca.

2. Robert

Robert was the only male subject/participant of this study. At the time that these interviews took place, the White nineteen year old was in the second semester of his freshman year. In high school, Robert took four science courses, including one advanced placement course. Robert indicated that while all of his high school science courses had laboratory exercises associated with them, none of them had a separate laboratory component.

An aside must be mentioned before the results of Robert's data are discussed. Due to tape recorder malfunction, the transcription from Robert's first interview is unavailable. The results that are described for the first interview are taken from the field notes from Interview 1, which were written directly after the completion of the interview. While some of direct quotes from the first interview may not be exactly correct, the proximity of the write up of the field notes to the actual interview suggests that the field notes are a suitable proxy to the transcription.

Robert indicated during the first interview that he held low self-efficacy beliefs about his science abilities. According to Robert, "I have been good at every subject but science." Robert's beliefs were supported when he discussed his actions in his high school science classes. When he was asked to recall information about his high school science laboratory activities, Robert's response was "I didn't do them."

Further elaboration on his comment revealed that rather than engaging in the laboratory activities, Robert copied the results of the assignments from his classmates. Robert's actions of avoidance are what would be expected for someone with low self-efficacy. Further evidence of Robert's science self-efficacy beliefs occurred when he expressed performance outcomes for those science classes. Robert referred to his high school science classes as a "waste of time," indicating that his main goal was to complete the assignments without fully understanding or engaging in them.

Despite Robert's apparent low science self-efficacy, he seemed to have high self-efficacy when it came to the astronomy course. When he was asked how the course was going for him, Robert replied, "I'm doing fine." Another indication of Robert's high astronomy self-efficacy came when he was asked about his expected grade for the course. According to the field notes, Robert confidently replied that he expected a B in the astronomy course. During the course of the interview, Robert rated the difficulty of the astronomy course when he said, "It's not harder than chemistry, but physics was easier." Robert's numerical rating of a seven out of ten for the difficulty of the astronomy course seemed to agree with that statement. Robert's low science self-efficacy explains his tendency to avoid classes that he perceives as hard. Robert indicated that he enrolled in the astronomy course because he perceived it as being "easy" and a course in which "I could get a better grade."

The main source of Robert's self-efficacy beliefs from the first interview seemed to be from authentic experiences. An example of Robert's use of authentic experiences came when he referred to the phases of the moon laboratory assignment as “the most effective because you got to move like the moon moves.” Similarly, Robert discussed his preferences for the types of laboratory activities he would rather have when he said, “the celestial sphere doesn’t help me understand where things are in the sky.” Instead, Robert indicated that he would rather go outside and “find polaris and identify stars to see them.” Robert’s discussion centers on having ‘hands-on’ authentic experiences rather than having removed experiences. As expected for someone with high self-efficacy, Robert gained self-efficacy information from his successes in the classroom.

Robert briefly mentioned the role of his partners during the first interview. According to Robert, “We put our heads together to figure (the exercise) out,” indicating that although minor, he did rely on working with a partner to help him through the assignment. When he was asked about the functionality of his partnership, Robert indicated that most of the time it was an even split, with both of the partners doing an equal amount of work during the classes.

Task difficulty and effort were the two main attributions that Robert had at the beginning of the semester. Of the two, task difficulty seemed to be stronger, as Robert’s discussion more frequently centered on it. Robert mentioned the difficulty level of the astronomy course in general as well as the difficulty level of the course assignments. Even though Robert studied harder for his astronomy examination than he claimed to study for any other course, he declared, “other times it’s not too bad.” Robert also mentioned the difficulty of the laboratory assignments when he was asked about how he functions without a partner, “No, that lab was the easiest we had so far. I actually worked faster alone than with my partner but that was because this lab was so easy." Again, Robert attributed his performance on the laboratory assignment to the difficulty of the task rather than to his ability to understand the assignment.

Along with task difficulty, Robert discussed the amount of effort he put forth in the astronomy class. Robert indicated that he spent more time studying for his astronomy examination than he did for any of his other classes. When he discussed his self-efficacy beliefs about science Robert also indicated his attributions when he said, "if I didn't do any work for science, I wouldn't do well." Unlike most of the other subjects, Robert recognizes that his effort affects the grade he receives, "My work has affected my performance, but that's the same as it is with everything." Apparently Robert identified the significance of putting forth effort in order to achieve success, although that point seems to be lost when it comes to his general science self-efficacy.

The confidence that Robert exuded during the first interview had waned during the second. From the start of the interview, Robert indicated that he relied on help from his teaching assistant in order to understand the laboratory assignments. When he was put on the spot and asked how he believed he would perform if given a laboratory assignment right then, accompanied by a nervous laugh Robert replied, "Not so well." Robert was asked why he believed he wouldn't do so well, to which he responded that he would not remember the assignments that he had previously performed, especially from the beginning of the semester. Another indication of Robert's changed self-efficacy became evident when he said, "I was really hot until we go into… two and three weeks ago, and then we got into like emission spectra." Robert's low science self-efficacy took over at that point, especially when he added, “this is like the part of science I was trying to avoid by taking astronomy… it’s just like chemistry all over again.” While Robert’s placement of his astronomy understanding near the top of the class at first glance would appear that he had high self-efficacy, he granted himself that status because, “not because I know so much, more so because (my classmates) don’t know a lot. I guess they don’t pay attention during class.” Robert’s response spoke directly to his sources of self-efficacy information.

Unlike the beginning of the semester when Robert obtained most of his self-efficacy information from authentic experiences, the second interview revealed that Robert gained a lot of his information vicariously. Robert spoke to the importance of having a laboratory partner on several occasions. When he was asked how he would perform on an assignment without a partner, Robert replied, “Not too well… I think it’s an important part… there are some labs that like, take a lot of thinking that you really need two people for.” He adds, “I would say for most I would do a lot worse.” Robert obviously depended on his partner to help him through the laboratory assignment.

Similarly, Robert relied more on his teaching assistant’s help during the middle of the semester than he had previously. Robert referred to the “helpfulness” of his teaching assistant repeatedly. From the beginning of the interview, Robert made statements such as, “I end up asking questions like as I’m doing the lab anyways,” and “I’m doing the lab I usually get help and it works out fine.” Later, Robert elaborated on the extent to which he relied on his teaching assistant when he said, “I would not get good scores on the lab if she was going to be like, ‘you know what, you should have listened to my description.'" Robert's dependency upon his teaching assistant was also apparent when he answered the question about completing a laboratory individually, when he responded by saying, "I would just ask my TA more questions, so that might even it out."

While Robert's self-efficacy and self-efficacy sources shifted between the first and second interview, his attributions remained the same. Robert responded to the question of whether he is finding the laboratory assignments challenging with a resounding "No," and elaborated by saying that he finds the assignments straightforward. If he did encounter a tough question, Robert simply asked his teaching assistant for help. The indication from the second interview was also that Robert's efforts from the beginning of the semester are continued through the middle, only studying hard for the examinations and nothing else. Robert's efforts toward the non-examination assignments in the astronomy class support his attribution about the difficulty of the assignments.

Robert's astronomy self-efficacy, while lessened toward the middle of the semester, seemed to strengthen by the end of the semester. Continuing to refer to the astronomy course as "easy," Robert appeared to regain his confidence, especially when he said, "I'm understanding astronomy, which is good." Unfortunately, the same could not be said for Robert's general science self-efficacy. In the same breath that Robert claimed to understand astronomy, he claimed, "I'm definitely not a science kind of student… (science is) the one subject that like, all throughout high school I had problems with." Robert's science self-efficacy was even further demonstrated when he discussed his reasons for taking astronomy, "it's better than the alternative of me taking a bio class which could end up a C or a D." This comment came after Robert claimed that he would "probably going to get a B in the (astronomy) course."

Robert's dependence upon vicarious experiences increased from the middle to the end of the semester. Robert's main topic of discussion during the final interview was the role his laboratory partner played in helping him understand the assignments. For example, Robert discussed his strategies for studying for the examination when he said, "I go over it with a friend, like right before the test, and then like, I generally know everything and I go into the test with confidence." Robert also claimed to "space out during the explanation" his teaching assistant gives during the beginning of the laboratory class, and how his partner, "usually explains what's going on and like why it works." On a scale of one to ten, Robert rated the importance of working with a partner a nine, because "some of them are difficult concepts." Of equal importance to having a partner, according to Robert, is having a partner that has the same amount of understanding about the course material. This is important because, "we like figure it out together, which… helps remember it better… when you figure it out than when somebody tells you like the right answer." Robert's emphasis on 'figuring it out' with his partner strengthened the role he places on vicarious experiences. Robert mentioned authentic experiences during the final interview, albeit briefly, and emotional arousal and verbal support are not mentioned at all.

Robert's attributions shifted only slightly between the middle and end of the semester. The emphasis that Robert previously placed on task difficulty was still apparent in the final interview. Robert mentioned the ease of which he found the astronomy assignments when he said, "the concepts in the lab aren't that hard." He also discussed how only "some of them are difficult concepts," and "as I'm doing it I figure it out." Evidently, Robert had no problem doing the laboratory assignments because they were easy to understand more than anything else. The disinterest that Robert had expressed about his high school science courses was emulated toward the astronomy laboratory during the final interview. Robert claimed, "sometimes the labs are not that fun," and that was why, "you like need another person to just like, casually talk to." The same feelings were reiterated when Robert referred to the laboratory assignments as "a task to accomplish" rather than a learning experience. Robert's feelings were also made clear when he stated, "I don't need the lab," indicating that he would prefer not having the extra work the laboratory added to the class.

Throughout the task, Robert seemed to be comfortable with the questions he was being given, despite his response that he did not believe he would do well on the questions. Robert's confidence became evident from the beginning of the meeting; when he was asked how confident he was that he would be able to answer the questions with the right answer, Robert replied, "not confident at all." Unlike some of the other subjects, Robert appeared comfortable with manipulating the objects provided for him. During the entire duration of the task, Robert manipulated the Styrofoam objects to help him with his thought process. Robert's apparent level of comfort with the objects and confidence in answering the questions suggested that his self-efficacy is underrated. Robert's actions during the task also seemed to support some of his answers from the second interview. According to Robert, he was confident with the astronomy course until he encountered subject material with which he had previous problems. Robert's self-efficacy judgments regarding a particular subject matter affected his confidence in being able to succeed in the course.

3. Kristen

Kristen was a nineteen-year-old White female in her second semester of her freshman year. Each of the classes Kristen had in high school, biology, chemistry, physics, and forensics, had activities or exercises that Kristen considered laboratory in nature.

When asked about her science abilities, Kristen replied that she considers herself "average" in science, and admitted that science was never her strong subject. Her self-efficacy beliefs became evident when Kristen spoke about having little interest in her science classes in high school. Kristen mentioned her laboratory exercises as "self-explanatory" and "straightforward," indicating that they required very little, if any, engagement in the actual activity. While Kristen indicated that she did not enjoy science, she speaks of getting "good grades" in her science subjects. The first interview with Kristen revealed that she attributed her performance in science to the amount of effort that was expended rather than her science 'ability,' as if science 'ability' is what is required to be considered "good" at science.

There was no evidence amongst Kristen's data to suggest the source of her self-efficacy beliefs. Kristen did not mention anything about her educational background that would suggest that a single source, such as a negative experience in the classroom, is to blame for her self-labeled "average" science ability. However, it was mentioned that Kristen had no interest in science as a subject, and therefore she exerted little effort in understanding the material. During the course of the first interview, Kristen discussed her emotions about not having to take another science course after astronomy. Given her self-efficacy beliefs, it is possible that Kristen displayed the same avoidance behavior typical of those who have low self-efficacy, opting to not challenge herself in order to avoid the possibility of failure.

The predominant theme throughout the first interview with Kristen was her interest in science subjects. Kristen mentioned that she decided to enroll in astronomy because she had always been interested in the subject, and she thought that it would be easier than some of her other options. While she mentioned that she was average in science, Kristen claimed to have high confidence in her ability to successfully complete the astronomy course. In this case, we will see that Kristen overestimated her astronomy self-efficacy, and her overestimation affect her performance in the class throughout the semester. As a result of her misjudged self-efficacy, Kristen did not exert a lot of effort toward her studies during the first few weeks of class.

Kristen's interest in the topics that were being covered in the astronomy laboratory played a role in the sources from which she drew her self-efficacy information. Several times Kristen mentioned enjoying the "hands-on" activities of the laboratory. As a result, Kristen mainly discussed the authentic experiences associated with the astronomy laboratory. There was less mention by Kristen of vicarious experiences, verbal persuasion, or emotional arousal in the first interview. For example, Kristen mentioned a particular laboratory, the 'celestial sphere' laboratory, several times during our first encounter:

> "I thought that was really interesting. "'Cause… we had like our own little globes that we got to actually move it around and see the shadows, like we were just told about the shadows before, we could actually see the shadows…I really liked that one (March 7, 2005)."

The celestial sphere laboratory was an exercise in which students were given a model that represented the Earth, Sun, and constellations, and asked to manipulate the model in order to investigate the sun's movement among the constellations throughout the Earth year. During each mention of the laboratory exercise, Kristen mentioned enjoying her "hands-on" experience. To Kristen, that exercise was an authentic experience about the Sun's movement.

While it was obvious that Kristen placed a priority on authentic experiences during our first interview, vicarious experiences were mentioned. Kristen discussed working with a partner in the laboratory classroom. According to her remarks, Kristen and her partner relied on one another equally in order to complete their assignments. Along with her comments, Kristen's brief mention of working with partners suggested that the vicarious experience contributed very little to Kristen's self-efficacy. When Kristen was asked whether she thought the astronomy laboratory would be easier with or without a partner, she replied "I guess it's easier (with a partner) 'cause you can discuss, but, it would also take a longer time." The emphasis that Kristen put on vicarious experiences elucidated information about her attributions during the first interview.

Kristen's attributions seemed to be in direct contradiction with one another. While she labeled herself with "average" science abilities, Kristen failed to recognize the connection between her efforts in a class and the envisioned "success." Her comment "I got decent grades at science, but, it's not my favorite," suggested that

Kristen believed an interest (emotional arousal) is necessary to succeed. During the first interview, Kristen believed that her interest in astronomy would facilitate her success in the course, despite her lack of effort or perceived ability. Even though she considered herself an 'average' science student, Kristen claimed that the astronomy course material is "not necessarily hard." The successes that Kristen achieved in the astronomy laboratory assignments must therefore be attributed to task difficulty.

The discrepancy between Kristen's self-efficacy and her performance had been reduced between the first and second interviews. While Kristen previously discussed her confidence in performing well in the astronomy course, she mentioned that her expectations for her course grade have changed. Kristen's anticipated grade of an A or a B in the first interview had changed to a "probably like between a B and a C… Hopefully a B." Not only had Kristen's anticipated grade changed, but her confidence in her ability to achieve the anticipated grade had changed. Kristen had declared her course outcome in the first interview with little hesitancy, but during the second interview, Kristen became less confident, mentioning the word "probably." The source of Kristen's self-efficacy change had apparently been the results of her first examination.

Kristen's change in self-efficacy was also apparent in a shift in her sources of self-efficacy information. During the first interview, Kristen mentioned authentic experiences and emotional arousal as the primary sources of her self-efficacy. In fact, the most common word Kristen uttered during the first interview was "interest." Directly contrasting the first interview, Kristen commonly referred to the guidance she received from her teaching assistant as well as her collaboration with a partner in the laboratory during the second. Before any specific questions were asked of her, Kristen mentioned the "helpfulness" of her teaching assistant's explanations. Similarly, when asked about her confidence in completing a laboratory assignment on the spot, Kristen asked, "would I be able to ask questions?" Her initial response was that she would be able to complete the assignment, but upon thinking about it, Kristen's reply changed from a firm answer to "I don't know how well I'd be able to answer them, but… I'd be able to complete it."

The reliance that Kristen had on her teaching assistant was also apparent during the second interview when she discussed the pending examination. Kristen's concern over her first examination grade prompted her to seek help from her teaching assistant for the second exam:

> "She told me that, um, I should come talk with her like before the next test, and she'd help me, like, you know, go over some things and I should come to her office hours, so she's definitely helpful (April 11, 1005)."

Through her comments in the second interview, it would appear that Kristen placed more emphasis on the teaching assistant's encouragement than she did previously.

Despite Kristen's claims that she was more confident during the second interview than she was at the beginning of the semester, Kristen's actions suggest that her confidence has decreased. Kristen's change in self-efficacy is demonstrated when she discussed working with a partner during a particular laboratory assignment. When Kristen was asked to describe a situation that was stressful to her, she discussed a situation where she was paired with a partner with less understanding than she. Although it was not directly addressed, Kristen's description of the situation suggests that she placed more emphasis on vicarious experiences than she admitted. Kristen said, "I was worried that I wasn't giving her like the right instructions about which, where the lines were or what colors they were," suggesting that her self-efficacy was more apparent when she, rather than her partner, was responsible for successfully completing the laboratory assignment.

Along with a shift in self-efficacy and sources of self-efficacy information, Kristen's attributions shifted between the first and second interviews. Kristen originally attributed her success in the astronomy laboratory to 'interest,' but it was apparent during the second interview that her attribution had changed to 'effort.' As a matter of fact, there was little mention of the word 'interest' during the second interview. Since Kristen recognized the discrepancy between her initial self-efficacy, she adjusted her behavior, and discussed in detail the amount of effort that she was exerting toward the astronomy class. Kristen said things like "I know that I really have to study, focus on my homework…," "I'm going to make flash cards for the upcoming test…," and "I put more effort in now than I did at the beginning of the semester to raise my grade." An important aspect to mention at this point is that Kristen believed that she misjudged the difficulty of the course, and that 'task difficulty' played a more important role during the second interview.

At the beginning of the third interview, Kristen was asked if her confidence in astronomy had changed since the beginning of the semester, to which she responded "I think I've become more confident… my TA's I guess helped me understand the concepts more." Kristen's statement succinctly identified not only her self-efficacy beliefs about the astronomy class, but also her main source of self-efficacy information. Her familiarity with the course material enabled Kristen to improve her grades, which was the main measure of her success over the course of the semester. Despite her claims of feeling more confident in the astronomy course, when Kristen was asked about her science abilities, she replied “Not very good at all.” Kristen adds, “It’s one of my worst subjects… I’m glad to be getting all of my science assignments over this semester. I was never really good at science.” From her statements it would appear that Kristen’s overall perceived science self-efficacy has decreased over the course of the semester. Kristen’s self-efficacy beliefs are reiterated at the end of the interview when she states “I’m still very unsure of myself in science.”

Similar to the second interview, Kristen placed a large emphasis on the amount of help she gleans from those around her, including her teaching assistant and her classmates. Kristen placed even more emphasis on the role of her partners and classmates in her source of self-efficacy information. Several times, Kristen mentioned that it was “pretty important” to work with a lab partner, and placed that importance at an “8” on a scale from one to ten. Furthermore, Kristen discussed the importance of having a partner that has more understanding than she on the course concepts, because, in her words, “they’d be able to explain it to me better.” As with some of the other subjects, Kristen compared her performance in the laboratory classes to those of her classmates when she discussed her observations the time it takes her to finish an assignment. It seemed that Kristen used the vicarious experience of how long it takes her classmates to finish an assignment as a measure of her own self-efficacy.

Likewise with the second interview, Kristen mentioned her confidence in her success in the astronomy course with the help that she got from her teaching assistant. While the verbal encouragement Kristen is getting from her teaching assistant appears to be one of the stronger sources of self-efficacy information, the brief attention it is paid in the second interview suggested that there was another switch of the primary self-efficacy source between the second and third interviews.

The largest change between the second and third interviews is that of Kristen's attributions. In the time between the first and second interviews, Kristen's primary self-efficacy attributions changed from interest to effort and task difficulty. In the third interview, effort was the attribution that was emphasized the strongest. Most of the questions that were asked of Kristen in the third interview were answered with some discussion of how she has increased the amount of effort she exerted toward her coursework. Kristen made mention of things like "I …actually put some work into the class," "I could read and know what was coming up next," and "I usually take the time to understand and ask questions." Kristen attributed her increased effort towards the class with improving her class grades. As for the previous attributions that Kristen mentioned, task difficulty was briefly addressed when Kristen mentioned that she underestimated the difficulty of the course, and her 'ability' to understand and 'interest' in the course material is not mentioned at all.

Kristen's decreased science self-efficacy may be a result of a combination of factors. First, Kristen viewed the subject of astronomy as "not that much science," thinking of the subject as less difficult than some of the other science subjects to which she had been exposed. Given her beliefs about the subject and the difficulties she encountered, Kristen's perceived self-efficacy may have decreased as a result. Although she never mentioned it, Kristen's adjusted self-efficacy suggests that she believes science is an 'ability' that a person 'has' rather than a 'subject' that a person 'learns.' This explanation is further supported given that it is harder to change the attributional belief that science is an ability rather than a result of effort, considering that Kristen saw an improvement in her astronomy grades when she increased the amount of effort she exerted in the class. The result of Kristen's attributional beliefs is that she must not be 'good' at science if she has to exert more effort than that of her classmates.

The second factor that may have played a role in Kristen's decreased perceived self-efficacy is the increased amount of emphasis that she placed on her vicarious experiences as a source of self-efficacy. At the beginning of the semester, Kristen relied mainly on her interest and her 'hands-on' experiences to judge her science self-efficacy, both in the astronomy classroom and on her prior experiences. With a perceived failure, Kristen shifted to relying more on the vicarious experiences of her classmates, including relying more on partners and judging her performance based on how long it took to complete an assignment, to judge her self-efficacy. An increased dependence upon her classmate's experiences seemed to lower Kristen's science self-efficacy as she witnessed herself taking longer to complete assignments. Kristen's dependence was also demonstrated in her shift from feeling as though she was equal with her laboratory partners to desiring a partner who had a greater understanding than she. The mode of comparing Kristen's own performance to that of her classmate's experiences seemed to be increasingly detrimental to her self-efficacy as the semester progressed. So, while Kristen gained confidence in her ability to complete her astronomy assignments, her view of astronomy as a 'lesser' science coupled with her dependence upon her teaching assistant and classmates lowered her overall science self-efficacy.

From the onset of the task completion, Kristen exhibited behaviors that suggested that she was not confident with the material that was being covered. When she was asked how confident she was that she would be able to answer the questions correctly, Kristen replied, "I don't remember all of the, lab, but um, fairly confident, sure." The lack of confidence with which Kristen responded to the question was apparent throughout the remainder of the interview. Despite being provided with materials to aid her thought process, Kristen hesitated to use them until she was reminded that the materials were there for her to use. Kristen's responses repeatedly included phrases such as "I'm not sure," "I don't know," and "this is really confusing." Recall that Kristen claimed that she felt more confident in the second interview than she had in the first, yet her responses to questions in the second interview suggested otherwise. It was evident from both the task completion and Kristen's responses in the second interview that she had overestimated her self-efficacy.

4. Samantha

Samantha was a White female, in her second semester of her freshman year at the time of this study. Samantha's educational background included three high school science courses, all of which had laboratory components.

Interviews with Samantha were brief, the longest of which lasted only ten minutes. The brevity of Samantha's answers suggested that she was not open to the interview process. It was possible, however, to gather information about Samantha's self-efficacy beliefs from the few words that she spoke. Right away Samantha mentioned that she had very little interest in science. When she was asked whether or not she enjoyed any of her high school science classes, Samantha responded "none of them." Samantha's disinterest in her science classes was directly related to her self-efficacy beliefs, as indicated in her statement, "I'm not really a science person, so I didn't understand a lot of them." It was obvious that Samantha had low self-efficacy and was displaying avoidance behavior. Samantha's avoidance behavior was displayed further when she described why she enrolled in her astronomy class, "I thought it was going to be easy." In addition, Samantha blamed her previous teachers for her lack of scientific understanding, "Maybe I had bad teachers. They didn't help explain anything when I asked questions." Despite Samantha's admittance that she grew more comfortable with subject-specific science material after having taken a course, she indicated that her enrollment in a science course had no effect on her overall science confidence.

Since self-efficacy is subject-specific, it could be possible that Samantha's astronomy self-efficacy was different from her overall science self-efficacy. At the very least, the first interview would elucidate Samantha's feelings about taking the astronomy class. Right away, Samantha's science self-efficacy was apparent when she made the statement, "…it wasn't like bio or chem or anything that sounded hard." Like many of the other participants with low self-efficacy, Samantha had enrolled in the astronomy course in an attempt to avoid possible failure because she thought it would be easy. The most important source of self-efficacy for Samantha during the first interview was the authentic experience.

Samantha's self-efficacy became the most evident when her description of several laboratory assignments were compared against one another. When she was asked about a specific "hands-on" laboratory assignment, Samantha described it as "difficult," and continued on to discuss her interaction with her laboratory partner. Describing her partner as "pushy" and "really concerned with getting out of the lab as fast as possible," Samantha discussed how he would not allow her to manipulate the object for herself. Samantha blamed her partner's actions for her own lack of understanding. A similar description occurred when Samantha described another "hands-on" laboratory assignment. While she could not recall why that particular laboratory assignment was difficult, Samantha claimed that she doesn't "have good spatial ability," and "can't just visualize things in the air." Rather than challenge herself to determine where she was having difficulty, Samantha ignored the thought altogether. In contrast, Samantha described a laboratory that required only basic observation skills as "easy" and claimed that it "was pretty hard to go wrong with that."

The two most common themes in the first interview, lack of interest and lack of effort, can be linked to one another. Samantha found that the laboratory assignments were "busy work a lot of the time," and claims that "if I tried a lot harder I could get an A." Samantha's statements suggest that her lack of interest is the cause of her lack of effort, it is possible that *both* her disinterest and her lack of effort are attributable to her self-efficacy beliefs.

The distinct lack of responses given by Samantha that permeated the first interview continued in the second. Samantha's self-efficacy beliefs did not appear to change much, if at all, between the first and second interviews. When she was asked to compare her astronomy understanding to that of her classmates', Samantha described her own understanding as "either the same or… a little bit less than them." It was apparent that the same disengaged behavior that Samantha described in the laboratory classroom occurred during the interviews. Despite her previous indication in the first interview that she preferred working on her own, the responses that Samantha supplied in the second interview suggested that her preferences changed.

The main source of Samantha's self-efficacy information during the second interview seemed to be that of verbal persuasion. Samantha recalled several instances during her laboratory exercises where she relied on either her classmates' or teaching assistant's help in order to complete the assignment. Relying on others for help was only hinted at during the first interview, but it formed the bulk of Samantha's responses during the second. Samantha said things such as "If I have people helping me during the lab, I'll kind of understand what's going on, but if I'm like left to myself then I won't understand," and "I pretty much asked the TA a whole bunch of questions, so, she kind of helped me do the lab." It was obvious from Samantha's responses that she did not trust her own abilities enough to rely only on herself to complete the assignments.

Samantha's attributions were hard to determine because of the lack of response that she gave during the interviews. However, the lack of effort pattern that had been established during the first interview appeared stronger during the second. Samantha's adamancy regarding the subject matter had grown stronger during the second interview, as evidenced by responses such as "I'm just not interested in this at all," and "I would try to find something that was more interesting to me." Regarding Samantha's own effort, she claimed, "I still don't read for this class," "I spend even less time doing the stuff in this class," and "…they grade pretty easy anyway so I don't try too hard." Given Samantha's previous comments regarding her potential performance if she put forth the effort, it was more obvious during the second interview that Samantha's lack of effort was a self-preservationist tactic. Basically, Samantha convinced herself that if she performed poorly in the classroom, it was not because of her abilities but because she did not apply herself. Given the above inference, it is possible that Samantha believes science is an inherent ability rather than something learned.

The final interview with Samantha was the shortest of the four meetings. Samantha's astronomy self-efficacy had risen over the course of the semester due to her familiarity with the subject. She recalls being "nervous" about the expectations for examinations, but was alleviated when her resulting grades were a success. Despite her success in the astronomy class, Samantha still claimed, "I wouldn't say I'm a science person," showing that her overall science self-efficacy had not changed. It is possible that Samantha's resulting science self-efficacy had not changed because of her views that astronomy is an easy science. Indeed, an expected success does not change self-efficacy beliefs in most cases.

One of the most apparent changes in Samantha's responses over the course of the semester was her opinion of her dependency on her classmates. In the first interview, Samantha had discussed finding individual labs easier than on those that she worked with partners. However during the second interview, Samantha frequently discussed asking partners and her teaching assistant for help. In the final interview, Samantha's discussion returned to the lack of her need for a partner, but still included requiring help from her teaching assistant. Samantha's change in verbal persuasion seemed to mirror her own astronomy self-efficacy. As her self-efficacy increased over the course of the semester, Samantha relied less on verbal persuasion as her self-efficacy source and more on her authentic experiences.

Analysis of the third interview also revealed that Samantha's attributional beliefs changed between the second and third interviews. While it appeared that she attributed success to science ability in the second interview, Samantha's attributions shifted to task difficulty in the third. There were several instances where Samantha commented on the difficulty of the laboratory assignments. Samantha's comments to this nature included things like, "most of the stuff is pretty easy." Comments of a similar nature were made when Samantha was asked about the importance of working with a partner in the laboratory, "probably like a two," she said, "because really if you have any questions you just ask the TA and they'll help you. You don't really need a partner for anything." Samantha's views on the amount of effort she was putting forth in the class changed as well. When she was asked about how hard she has worked to understand the material, Samantha replied, “fairly moderately hard.” This despite her claims during the second interview of putting forth very little effort in the class.

The same pattern of disengaged behavior that Samantha exhibited during the interviews was apparent during the task completion. Throughout the task, Samantha made very little effort to consider the questions that were being asked of her. When she was asked about her confidence in answering the questions, Samantha replied, “Not very high.” It was difficult to establish Samantha’s self-efficacy beliefs based on the task activity, given that she gave very little thought to the questions. However, the Samantha’s insistence that she put forth little effort toward the astronomy class was supported based on the task results. What could also be established was that Samantha’s response to the confidence question was apparent based on her responses to the questions. There were several instances where Samantha questioned her responses, with words such as “um, sure, okay,” “um, no?” and “yeah, I don’t know.” Samantha made very little effort to think about the answers, and therefore tended to answer the questions with uncertainty.

5. Carrie

Carrie was a 19 year old White female in her second semester of her freshman year during the time our interviews took place. In high school, Carrie took four science courses, all of which had a laboratory component associated with them.

Like many of the other subjects, Carrie did not consider herself a "science" person, and described her science abilities as average. Carrie's description of her science abilities included saying, "science has never been my strongest subject," and describing herself as an 'artsy' person. Carrie's self-efficacy beliefs seemed to stem from her reliance on her peers for her self-efficacy information. Often times Carrie would describe a situation where she would need more time to understand material than her peers. Even before discussing the astronomy laboratory, Carrie described finding working with partners 'helpful,' especially she said, when "you're unsure of things you can sort of pool your ideas together."

It was apparent from the first interview that Carrie attributed scientific understanding to an inherent 'ability.' She often spoke of her partners having various 'levels' of science understanding. Interestingly, Carrie recognized that her effort in a class resulted in an improved grade, but she still held firm on her beliefs about science as an ability.

As mentioned above, Carrie described her science ability as 'average' in the first interview, even though she claimed to have increased confidence in the astronomy course when she said, "I feel more confident about this class, in general, 'cause I know exactly what to do and what to study." There is a disconnection between Carrie's general science self-efficacy beliefs and her astronomy self-efficacy beliefs. With other subjects, the disconnection was a result of their views of astronomy as an 'easier' subject, but Carrie made no mention of such beliefs during any of the interviews. The reasons behind Carrie's disconnection were elucidated however, when her sources of self-efficacy information were examined.

Carrie's responses during the first interview suggested that she draws on all four of the self-efficacy sources of information, authentic experiences, vicarious experiences, verbal persuasion, and emotional arousal, almost equally. While relying on the four sources nearly equally ensured that Carrie most likely had a realistic view of her astronomy self-efficacy, as seen from other subjects, deriving self-efficacy information from verbal persuasion and vicarious experiences can be detrimental to overall science self-efficacy. In order to further understand this relationship, each of the sources of self-efficacy information is discussed in turn.

Carrie's dependence on authentic experiences was apparent through comments she made about her past science laboratory experiences as well as her current astronomy laboratory experiences. When she discussed prior experiences, Carrie described finding "hands-on" experiences a helpful contributor to her scientific understanding. For example, Carrie discussed an experience she had in her physics course, "the roller coaster project in physics… was definitely helpful." Similarly, Carrie described one of her interactive astronomy laboratory assignments and said, "..I liked that. It gave me a better idea of what I was doing." From these comments, it was evident that Carrie relied on authentic experiences to add to her self-efficacy beliefs.

Vicarious experiences were slightly more important to Carrie's self-efficacy beliefs, not only evident by the emphasis with which they were mentioned, but also by the comments she made about her previous science laboratory experiences. Even before she was asked, Carrie mentioned working with partners. Carrie's past reliance on vicarious experiences was further obvious when she discussed working with a partner on a project in high school. Furthermore, Carrie mentioned the importance of a partner's 'level of understanding, "it wouldn't be very helpful to work with someone who was, you know, unwilling to really give their input or ideas, or if they weren't a very bright classmate…I think it helps when somebody else knows a little bit more." Carrie's words echoed several of the other subjects who also relied on vicarious experiences as a source of self-efficacy information. The strongest evidence of Carrie's dependency on the experience of others was when she was asked if she considers herself good, average, or poor at science and said, "It just takes me a little longer than others to grasp ideas, I guess."

The results of the first interview suggested that Carrie depended just as much on verbal persuasion as on her authentic experiences. There were several occasions where Carrie recalled asking her teaching assistant to help her with her laboratory assignments. "I make sure to ask questions," "Melanie (her teaching assistant) is always there to um, answer questions that we have, so… you don't feel like you're completely lost and can't get any help," are few of the such statements that Carrie made regarding her teaching assistant's help. Carries support from, but lack of dependence on her teaching assistant suggested that Carrie has a realistic view of her own self-efficacy.

The fourth source of self-efficacy information, emotional arousal, seemed to also play a role in Carrie's self-efficacy beliefs. Carrie's dependence on emotional arousal became clear during her discussion of her high school science courses. Carrie described her physics class as 'fun,' and her chemistry class as not her 'favorite.' When she discussed the resulting performances in each class, both performances seemed to reflect Carrie's interest in the classes. This sentiment is echoed in Carrie's description of some of her astronomy laboratory assignments. There was one particular assignment that Carrie found "overwhelming" and "confusing," to which she claimed to have to work harder so she doesn't "fall behind." On the contrary, for those laboratory assignments that Carrie "liked" she had an easier time with. Along the same lines, Carrie's 'nervousness' about the course deteriorated as the course progressed.

Carrie's attributions during the first interview were similar to most of the subjects of this study. One of the contributing factors to low self-efficacy is attributing successes and failures to either external or internal sources that are uncontrollable. Carrie's description of her efforts in the astronomy class is the strongest evidence that she viewed scientific understanding as an ability that is owned rather than something that can be learned. While Carrie found some of the course material difficult, the overall difficulty did not seem to be a strong attribution. Part of Carrie's coping mechanism was to put forth greater effort when she experienced greater difficulty in the course. Despite her extended effort, Carrie still attributed success in science as ability rather than from effort. Carrie admitted to having increased confidence in astronomy because she was aware of the course "expectations," yet her confidence was confined to her success in astronomy, not her overall science self-efficacy. As discussed with previous subjects, it was possible that dependence upon vicarious experiences as a source of self-efficacy information can be detrimental to self-efficacy beliefs, especially when someone's abilities are viewed as less than their peer's abilities.

The trend that began during the first interview of Carrie's increased self-efficacy toward astronomy continued during the semester, and was obvious during the second. When she was asked during the first interview of her expected astronomy grade, Carrie replied "I'm hoping to get an A or a B," but when the question was repeated during the second interview, Carrie responded firmly with "an A." However, unlike the first interview, Carrie's increased self-efficacy had a greater dependence upon those around her. Despite her claims during the second interview that she was "more confident" in astronomy now than she was during the previous interview, Carrie still maintained, "I'm not really a… scientific-mathematic kind of person." Another interesting comment that Carrie made, "[this class] let me know that I'm not going to be studying anything in the math or science area," suggests that Carrie's enrollment in the course *confirmed* her self-efficacy beliefs. A closer look at the shift in the importance of Carrie's sources of self-efficacy beliefs explains the dichotomy between Carrie's astronomy and science self-efficacies.

The examination of Carrie's sources of self-efficacy information during the first interview revealed that all four sources of self-efficacy information were relied upon nearly equally. During the second interview however, Carrie's responses suggested that she relied more heavily on verbal persuasion than she had previously, both from her classmates and from her teaching assistant. Carrie was asked how well she believed she would perform if she were given a laboratory assignment to complete on the spot. Right away, Carrie indicated her dependency upon the help of others to complete her assignments. In response to the question, Carrie said,

"I can't say that I'd do excellent. I mean, if you gave me some… explanation of what I was going to be doing, and then, kind of work or assist me as I went along, then I might do okay. …I feel like I work better when other people are around (March 8, 2005).”

Carrie demonstrated an increased dependency on verbal encouragement, especially when she claimed that she knew “my TA is available to help me,” and “I have the option of getting help.” Unlike the first interview, Carrie rarely mentioned her interest in the subject material.

While Carrie mentioned her classmate’s abilities on several occasions during the first interview, the subject was mentioned only once or twice in the second. The emphasis that Carrie placed on her classmates’ abilities suggested that her dependency upon her judgment of her classmates’ abilities was still important, but took a lesser role in her own self-efficacy judgments. Again, Carrie’s discrepancy between her astronomy confidence and her science self-efficacy was apparent when she placed herself in the middle of the comprehension spectrum. According to Carrie, “there are people who have… less comprehension or understanding of the astronomy concepts than I do and then there are people who are more advanced and they’ll understand more.” So, while Carrie was confident that she would perform well in the classroom, she still rated her astronomy understanding as average. Part of Carrie’s beliefs can be explained through her attributions.

Carrie’s attributions shifted slightly between the first and second interviews. Comments such as the ones quoted above suggest that while Carrie was experiencing success in her astronomy course, she believed that success was not a result of her abilities but of her efforts. The amount of effort that Carrie put toward her comprehension of the material seemed to support her original self-efficacy beliefs that scientific understanding is a result of ability, and that ability requires no effort in order to achieve academic success. Carrie admitted to finding the astronomy course "challenging," which also seemed to support her attributions. Furthermore, Carrie attributed her success in the course not to her scientific 'ability' but to her 'efforts' such as working on extra-credit, or to being "in the know." Carrie had previously hinted to attributing her confidence to being aware of expectations, but her responses during the second interview suggested that her beliefs about prior knowledge were even stronger.

The final interview revealed that Carrie's self-efficacy beliefs really did not change much over the course of the semester. Once again, Carrie said that she had increased confidence in her astronomy class, but that she considered herself an 'average' science student. Carrie claimed that she worked with a partner who had "…a better grasp of concepts of like astronomy and science and math in general…", revealing that she still gained self-efficacy information from her peers.

Carrie's responses during the second interview suggested that the majority of her self-efficacy sources of information came from verbal persuasion, but it appears that by the end of the semester, Carrie had gained just as much information from vicarious experiences. When Carrie was asked how important working with a partner was to her success in the course, on a scale of one to ten Carrie rated it "an eight or a nine." Carrie claimed to feel 'comfortable' asking her partner for help because as she said, "then I know exactly what I'm supposed to know, what level I'm supposed to be on," as opposed to the 'expert' level of her teaching assistant. The importance that Carrie placed on working with partners was also iterated when she was asked about how she would change the laboratory course. Carrie claimed that she would keep “that we get to work with people and it’s not completely, um, individual work,” implying that vicarious experiences were important to her. Carrie’s vicarious experiences also came through observations of her classmates. When Carrie was asked about her science abilities, she compared herself to her classmates and said, “it doesn’t come as easily to me as I think it does to a lot of other people… I definitely can understand things but I have to work a lot harder.” The role of authentic experiences while relied upon by a lesser degree, were still important to Carrie. According to Carrie, “the easiest is probably, um, when they have like some sort of visual to help me out,” suggesting that ‘hands-on’ experience is important to Carrie’s learning. The role that emotional arousal had played in Carrie’s self-efficacy seemed to be non-existent by the end of the semester.

As with the second interview, Carrie’s attributions in the final interview seemed to be mainly ‘ability’ and ‘prior knowledge.’ There were many instances where Carrie discussed her confidence in the context of knowing “what to expect” and “having background knowledge” of her assignments. By the end of the semester, it was possible to assign Carrie’s attributions to individual self-efficacies. Carrie’s confidence in a success in her astronomy course was a result of having prior knowledge of the material, while her overall science self-efficacy was a result of her belief in scientific ‘ability.’ It made sense that Carrie’s science self-efficacy was not changed throughout the astronomy course; especially when she attributed her success to prior knowledge and not to her own abilities. Furthermore, it should be expected that Carrie’s science self-efficacy is confirmed when she gains so much of her self-efficacy information from the vicarious experiences of others. According to Carrie, her classmates understand the material much easier and with less effort than she.

Carrie's responses during the task completion activity emulated her responses to her the interview questions. When Carrie was asked how confident she was that she would answer the task questions correctly, she replied, "Um, not extremely confident, but, I don't know. I'll try." Carrie's response indicated that despite not being confident, she would put forth effort in order to respond to the questions. Similar behavior was indicated by Carrie in her interviews. Throughout the task completion, Carrie appeared to be working through her responses, thinking through her responses out loud. Carrie's behavior during the task completion activity suggested that while she may not have been extremely confident with her comprehension of the material, she had higher self-efficacy regarding her ability to cope with the material.

6. Emily

Emily was a twenty-year-old White female who was in her second semester of her sophomore year during this study. In high school, Emily took three science courses, one of which had laboratory activities associated with it. Before she enrolled in astronomy, Emily took a college biology class, which also had a laboratory section. What was particularly interesting about Emily's background was that she was an education major. Unlike the other subjects, some of Emily's discussion during the interviews reflected current educational thinking about learning behavior. Furthermore, as will be discussed in these results, the educational training that Emily received may have influenced some of her attributions.

Emily demonstrated her self-efficacy beliefs early in the first interview. When discussing her college biology course, Emily mentioned that she was only seventy percent confident in her performance. Similarly, Emily claimed that "science was never my strong point," and that "I'm more of like a English, math type person." Emily's science self-efficacy beliefs were also reflected when she discussed her expected grade in the astronomy course, "I need a B," Emily said. Emily's thoughts on her expected grade suggested that earning a grade of an "A" was out of the question, and that earning the grade of a "B" was only possible because it was a requirement for her major. Emily also displayed behaviors of those who have low self-efficacy when she said that she would not "choose" to take another science course if she did not "have to." While the original source of Emily's science self-efficacy was not revealed during the first interview, the main sources of her self-efficacy beliefs were.

During the first interview it appeared that Emily gathered a lot of her self-efficacy information through vicarious experiences. One of the main themes that Emily repeated was that of relying on her classmates to help her through the laboratory assignments. Emily said things like "'cause sometimes we have to work alone. I don't like that," "a lot of times people learn best through peers," and "…different people… have more knowledge than other people." Each of these instances indicated that to Emily, one of the most important aspects of learning in the laboratory classroom was leaning on peers for support.

Almost as important to Emily as vicarious experiences was that of authentic experiences. Emily described "hands-on" experiences as "interesting" and seemed to enjoy them much more than observational activities. One such experience was the assignment when Emily worked with the celestial sphere. Emily found the activity “much more interesting and more… informational.” In contrast, Emily described the introductory assignment, which consisted mainly of mathematical equations, as, “it was just like numbers, and it didn’t make sense to me.” From her discussion it was apparent that Emily found direct, relatable experiences as much more beneficial to her confidence in the astronomy class. Furthermore, when Emily was asked if her performance in the astronomy laboratory had influenced her astronomy confidence, she replied, “I think it’s helped out… I mean it reinforces and… allows you to like touch and feel and understand better,” also suggesting that the authentic experience added to her self-efficacy.

Emily gave several small hints that emotional arousal added to her self-efficacy beliefs, although the role was smaller than for vicarious or authentic experiences. When she was asked how she was finding the astronomy class, Emily replied, “I like it. But I’m also really interested in astronomy, always have been. I had to take another lab science and… this is the first thing I wanted.” Emily’s response indicated that while she was forced into taking another laboratory science class, (through the “I had to” comment), she was determined to take a subject that interested her. It was possible that Emily had more confidence about taking astronomy because she believed her interest would enable her to perform better than in a class in which she was disinterested. Similar comments were heard when Emily discussed the difficulty of the astronomy class, “Easier (than other classes). But once again, I don’t know if that’s because I actually like it, or if it’s really that much easier.

I think anything is easier if you like it." Emily's interest in the astronomy class partially explains her attributions.

During the first interview, Emily's attributions tended towards those of effort and task difficulty more than anything else. Emily indicated that she observed a correlation between the amount of effort she put forth toward the course exercises and the corresponding grades. With her examination and laboratory assignments, Emily indicated that she exerted more energy than toward her homework assignments. The result of her efforts was that Emily performed better on her exams and laboratory assignments than on her homework assignments. Emily recognized the efforts and resulting grades when she says, "The only thing I haven't done extremely well in is the homework. 'Cause I usually wait 'till like the day before to do it. And, if I have questions, I'm kind of screwed, so. But, that's my only downfall right now I think."

Emily's low overall science self-efficacy cannot solely be explained through her effort attributions; otherwise it would be much higher than it seems to be. While much of Emily's beliefs can be attributed to her efforts, she does hint that task difficulty and ability play a role in Emily's self-efficacy. When she discussed working with partners, Emily suggested that science ability exists, saying, "the boy didn't really know a lot, and the girl… she was knowledgeable sometimes and then not knowledgeable other times." Emily's beliefs about task difficulty playing a role in her self-efficacy became obvious when she described some laboratory assignments as "harder" or "easier." Task difficulty also played a role when Emily asked if her performance had changed from her initial expectations. According to Emily, she did not know what to expect from the onset of the course, but said, "I do hear now that it gets harder, so we'll see," indicating that she was unsure of her performance now that the course was to get "harder."

The results of the second interview indicated that Emily's self-efficacy had increased since the beginning of the semester. When Emily was asked to rate her astronomy understanding in comparison to her classmates, she responded, "I'm in the top, like, ten percent-ish." Placing herself in near the top ten percent of her class indicated that Emily has a very high astronomy self-efficacy, but her self-efficacy originally seemed to be only fair. Emily's astronomy self-efficacy beliefs were also heard when she described the laboratory assignments as, "they're not easy, and some are definitely easier than others, but they're all do-able." In contrast, Emily previously described an equal number of "hard" and "easy" laboratory assignments. Despite describing the laboratory assignments, as "not easy," Emily appeared to have confidence in completing the assignments, also suggesting her self-efficacy had increased. There is evidence to suggest that Emily had realistic expectations when it came to her self-efficacy. When she was again asked to postulate her final grade in the astronomy course, Emily replied, "I need to get a B, so I'm going to say a B… I mean, I can get an A, but I don't think that's possible." Emily's disbelief in her ability to earn an A in the astronomy course suggested that her prior performance in the course has raised her self-efficacy, but only a modest amount. As with other subjects, Emily's self-efficacy beliefs were explained by examining the sources of her self-efficacy information.

Emily's reliance on her classmates for self-efficacy information remained the same between the first and second interviews. Emily spoke of working with a partner just as often in the second interview as she did with the first. For example, Emily claimed to dislike individual laboratory assignments. When she was asked why, Emily replied,

> "…it's easier to like talk things through with somebody else if you're not like one-hundred percent sure on something. Like, talk it out, and then come to a conclusion together. If you're by yourself… you have to come up with the answer and so you're kind of stuck if you can't get it (April 15, 2005)."

Furthermore, when Emily was asked to give an example a stressful situation she encountered in the laboratory, she described a situation in which she and her partner had trouble with a particular assignment, "that stressed us out because we were completely unsure the whole time of what we were doing was actually right or not." While Emily had no problem with the assignments as long as she and her partner could work things out, she found a situation 'stressful' when they were both at a loss for what to do on an assignment. This response suggested that Emily still relied heavily on her peers for self-efficacy information.

Emily also relied on authentic experiences for self-efficacy information. There were several instances where Emily mentioned working with materials as more enjoyable and easier than other assignments in the laboratory. Emily said, "I like the ones when we actually look, have to look at pictures of like nebulas or stars, or you know, like work with actual, you know, stuff," indicating that "hands-on" experiences were important. When she was asked why this was her preference, Emily replied, "It's like real-life application… it's just easier to see the correlation between what we're doing." Emily's responses indicated that authentic responses still played a key role in her self-efficacy beliefs.

Emily still held firm to her effort attributions about her own self-efficacy during the second interview. Most of the discussion around Emily's performance in the astronomy class involved remarks about the effort that she puts toward the class. Emily recognized that while she put forth some effort, "I definitely could be doing a lot more." On the other hand, Emily previously mentioned having good grades on the laboratory assignments, and she recognized that "what I do…I put like all my effort into it. I don't like do it halfway. Always, like, I do all the extra credit and stuff." Unlike the first interview, Emily seemed to rely less on the difficulty of the task as an attribution during the second. Most of Emily's responses relating to the difficulty of the assignments indicated that she found the assignments easier than she had previously.

The third interview resulted in Emily's overall astronomy self-efficacy increasing, while her science self-efficacy remained the same. According to Emily, her confidence changed "definitely on certain things." Emily elaborated by saying, "Like I can actually sit down and explain, you know, like, certain aspects of the universe…" discussing various astronomy concepts that she understood better than she had prior to enrolling in the course. However, when she was asked to describe her science abilities, Emily replied, "I'm not like natural at it, no."

By the end of the semester, Emily seemed to gain most of her astronomy self-efficacy information from vicarious experiences. When she was asked about the role partners played in her understanding of the laboratory concepts, Emily replied, "A pretty big role, like all of us, like really work off of each other… if… my partner and I can't figure it out, then we'll ask the people in front of us and the people behind us, and everyone's… always helps each other out." Emily's dependence upon vicarious experiences was further demonstrated when she rates the importance of working with a partner a "ten" on a one to ten scale, with ten being the most important. In contrast to the previous two interviews, Emily did not mention having "hands-on" experiences in the laboratory, although she does feel like having outdoor activities would be more "engaging."

The reason behind Emily's lack of reliance on verbal persuasion is revealed during the final interview. When she was asked whether she would enroll in the laboratory portion of the astronomy course again, Emily replied, "I didn't not enjoy the lab, it's just I enjoyed the lecture more. But I think it was cause of the teacher. I think if I had a different TA it might have changed my opinion of the lab." Emily cited her teaching assistant's lack of experience as the reason why her teaching assistant, "just isn't really good at explaining things simply." It was evident that Emily did not feel comfortable relying on her teaching assistant for support, which might explain why such an emphasis was placed on vicarious experience despite Emily's high astronomy self-efficacy.

One of the most interesting aspects of Emily's responses in the third interview was that of the disconnect that exists between Emily's astronomy and general science self-efficacy. While her astronomy self-efficacy increased, Emily's science self-efficacy appeared to remain the same. The reason for the dichotomy between both self-efficacies can best be described through the separation that exists between Emily's attributions. While Emily gained confidence in astronomy, she recognized the direct correlation between the amount of effort she exerted and her performance.

The connection Emily made between her own efforts and her scientific understanding was best demonstrated when she says, "if I sit down and study like I did for the second test, like I have really good understanding." On the other hand, the fact that Emily's science self-efficacy appeared to remain constant suggested that Emily believes that scientific understanding is an inherent "ability," of which Emily believed she lacks.

The confidence that Emily appeared to have in being successful in the astronomy course was evident during the task completion activity. Emily's response to the question about her confidence in being able to answer the questions correctly was, "I'm moderate… this was one of the labs that I understood more, than others, so." Throughout the activity, Emily appeared to be thinking through her answers out loud, and although some of her responses seemed uncertain, her overall responses suggested that Emily was comfortable with the exercise. Unlike some of the other subjects, Emily was not hesitant to use the materials provided to her, and was comfortable enough to express her thought process. This behavior supports Emily's responses to the interview questions, where Emily claimed to be in the "top ten percent-ish" of her class when it comes to understanding the material.

7. Melissa

Melissa was a second-semester freshman, White female who was nineteen years of age during the time of the interviews. She had taken three high school science courses, one of which had a laboratory component associated with it. Melissa had not taken any other college science courses besides the introductory astronomy course that was being studied.

Melissa's self-efficacy beliefs were similar to many of the other subjects in this study. During the first interview, Melissa revealed, "science, it has always been… one of my subjects that…I'm not very confident in." She further elaborated, "I've never really been as confident in science as I am in other subjects," and called science one of her "weaknesses." Melissa's self-efficacy beliefs were further strengthened when she mentioned that she enrolled in the astronomy course because she was required to take a science laboratory course, and astronomy sounded like it would be an easy course. Melissa distinctly said, "I was like thinking 'Well how hard can it be to learn about the stars and the planets?'" indicating her belief that the astronomy course would not be difficult. Melissa further acknowledged her estimation of the astronomy course by saying that she originally believed she would earn a grade of an 'A' or 'B', but upon attending the class, she realized it would be more difficult.

Melissa's confidence in the astronomy course changed before the first interview took place. Originally, Melissa indicated that she felt that she was confident about her performance in the course, until she said, "until I got my first test back and it wasn't very good." Melissa added, "I'm kind of struggling right now." It appeared that Melissa had overestimated her self-efficacy beliefs initially, and a perceived 'failure' from her first examination grade corrected her self-efficacy beliefs, a correction that commonly occurs with overestimated self-efficacy beliefs. Melissa was also having difficulty with the laboratory assignments, claiming, "I'm kind of lost during the lab." Another example of Melissa's self-efficacy was when she was asked what her expected grade would be for the astronomy course. "Oh, a C," Melissa replied, without any hesitancy in her voice. Melissa's expectations for her course grade were most likely a result of her perceived 'failure' on the first examination and the subsequent self-efficacy adjustment.

As Melissa described her difficulties with test anxiety, it became apparent that the main component of Melissa's self-efficacy beliefs came from emotional arousal. While Melissa appeared to have moderate confidence in her ability to perform well on all of her other assignments, Melissa described having low test-taking self-efficacy. One of Melissa's coping strategies was to put forth a lot of effort in her other assignments because, "I've always been a really bad test taker." Melissa also described being "nervous" before the first examination and once, "the test got put in front of me and I just froze." It seemed that Melissa's self-efficacy would be much higher if it were not for her emotional distress about taking examinations.

The second most important contributor to Melissa's self-efficacy beliefs during the first interview was that of verbal support. That support came mainly in the form of help from Melissa's teaching assistant. Melissa indicated several instances where she relied on her teaching assistant for help during the laboratory sessions. Melissa's reliance on her teaching assistant was apparent when she said, "I always end up going to my TA and she helps me." Furthermore, Melissa described the degree to which she relies on her teaching assistant,

"I went to her with a homework question and I was just trying to, I was asking her how to explain how to get through it and she actually ended up sitting there going through um, she went through it step by step with me and helped me… we went to the lab room and she sat there with me and helped me. It was really helpful (March 9, 2005)."

Melissa was also asked if she found the course material more difficult or easier as the course progressed, and although she replied "difficult," Melissa added, "it's also nice for me to know that I can ask my TA questions and she'll be very helpful." In a sense, Melissa leaned on her teaching assistant to help her through the tasks required of the course.

To a lesser degree, Melissa relied on her classmate's experiences as a source of self-efficacy information. When she was asked how she finds working with a partner, Melissa replied, "I kind of like working with a partner better, because sometimes like, if I don't understand something that well, my partner does and it helps a lot, or vice versa." Her comment, along with the fewer discussions of partners indicated that Melissa gathered some of her self-efficacy information from those around her, but it is less important to her than working with her teaching assistant.

Melissa's attributions were difficult to ascertain during the first interview. Unlike previous subjects, Melissa did not refer to science 'ability' directly. In contrast, while Melissa mentioned science as one of her 'weaknesses,' she attributed that weakness to her interest in science more than anything else. Melissa's disinterest in science was reiterated when she said, "I just get bored with the whole subject of astronomy and… I don't really find it interesting." Melissa's interest attributions were further strengthened when she referred to the lunar phases laboratory assignment that she found interesting, "I found that kinda interesting and easy." She further elaborated on that topic later in the interview when she said, "I really, I understand the phases of the moon and all that so I guess I can say I'm better at that."

While Melissa mentioned the amount of effort she put forth in the class, her effort was always discussed as a coping mechanism rather than being attributed to her success. For example, Melissa said, "cause I do all my work, and you know, I do all my homework and I get good grades on that, and I try as best I can in the lab but I've always been a really bad test taker," indicating that her effort was used to counteract her 'bad test taking.' Melissa's self-efficacy beliefs about taking tests was further strengthened when she mentioned the amount of preparation she underwent before the first examination, "I studied all day the day before it… I went to the exam review, and I studied, and I woke up real early and I studied before." Despite Melissa's preparation for the examination, she perceived the result as a failure. Again, when Melissa was asked if she noticed if her effort toward the class paid off, she replied,

> "I know that if I didn't do the homework at my best ability, then there would be a chance that I wouldn't be able to pass the class because I, I kind of rely on doing all the work, and doing good on all the labs to pass the class because I know I'm not a very good test taker (March 9, 2005)."

It would appear that while Melissa's efforts resulted in successes in her assignments, her anxiety about taking tests took precedence and overshadowed those successes.

Evident from the onset of the second interview, Melissa's astronomy self-efficacy increased during the interlude between the first and second interviews, but her test-taking self-efficacy remained the same. Melissa claimed to be "doing fine" in the laboratory portion of the class, but mentioned, "it's just about the test." All throughout the second interview, Melissa mentioned that the laboratory assignments were "easy" and "straightforward." When she was asked how she thought she would do if given a laboratory assignment to complete on the spot, Melissa responded, "I think I'd do fine… because they're pretty straightforward." With her increased self-efficacy, Melissa's grade expectations had also changed. Previously Melissa believed that she would earn a grade of a "C" in the course, but when she was asked during the second interview, Melissa claimed, "I'm pretty sure I can bring it up to a B." Furthermore, Melissa was not concerned at all with her performances on non-test assignments, indicating that her self-efficacy had increased as a result of her 'successes' on those assignments.

While Melissa's astronomy self-efficacy appeared to increase between the first and second interviews, she still considered herself, "not really a science person to begin with." And despite recognizing her own increased confidence, when she was asked to rate her astronomy understanding in comparison to that of her classmates', Melissa replied, "I'm probably on the lower end… sometimes it seems like other people around me are so sure what they're doing." She adds, "Sometimes I just feel really stupid to ask." Melissa's comments suggest that the dichotomy between general 'science' self-efficacy and astronomy self-efficacy that has been observed with previous subjects was not as large with Melissa.

Along with a shift in self-efficacy beliefs, Melissa's sources of self-efficacy information also seemed to change between interviews. While Melissa obtained most of her self-efficacy information from verbal support during the first interview, she seemed to gain equal input from vicarious experiences and verbal support during the second. There were many instances where Melissa referred to relying on her classmates for help during laboratory assignments. For example, Melissa described the lunar phases laboratory assignment when she said, "I had a hard time comprehending," and added, "we would take turns measuring and, he was telling me if I did something wrong he would correct me, and he was pretty patient and everything." Melissa also stated, "working with the lab partner is always kind of good too." At the same time, Melissa mentioned the helpfulness of her teaching assistant with as much frequency during the second interview as she had during the first. Speaking about her teaching assistant, Melissa said, "If you have any questions she always comes and helps," and, "before our test, she'll give us basically like a study guide which is really helpful." Melissa also added, "I'm really glad I have her," indicating she still gained a lot of self-efficacy information from her teaching assistant.

There was a noticeable shift in Melissa's attributions between the first and second interviews. While Melissa's responses made it difficult to determine her attributions during the first interview, her responses during the second made them clear. During the second interview, Melissa attributed most of her success in the astronomy course to prior knowledge and effort. She referred to the course requirements when she said, "I think I will do a lot better on my test just because I know what to expect now." Melissa also discussed the amount of effort she extended toward the course in a different context than she had in the first interview.

The test anxiety that Melissa displayed during the first interview overshadowed the efforts that Melissa made toward the class. Thus, although Melissa experienced success as a result of her efforts during the first interview, Melissa was too concerned with her test anxiety to pay it notice. During the second interview, however, Melissa's continued success resulted in her increased self-efficacy. Melissa spoke extensively about the effort she exerted toward the astronomy class, "I've probably been putting more effort into this class than the other ones," she said.

Melissa also discussed her strategies for success when she said,

> "I pretty much every night I review over my notes, and I look on the website, and you know, try to answer the sample questions they have on the course website… I always get started really early on my homework and on the extra credit assignments... and I make sure to go to every lecture and every discussion and every lab. I haven't missed any of them (April 13, 2005)."

Melissa recognized that putting effort toward the class had resulted in the good grades she received on her assignments, and made sure to repeat that behavior to ensure her success. Melissa's increased self-efficacy had resulted in diminished test anxiety, but the results of the third interview revealed that Melissa once again overestimated her self-efficacy.

The results of the third interview indicated that Melissa's self-efficacy during the second interview had increased over her capabilities. Melissa recognized that she "did feel a lot better until I took my second exam," but the examination resulted in her being "back to where I was." Melissa encountered the same pattern with the second examination as she had with the first. The corrections in astronomy self-efficacy that Melissa experienced strengthened her general science self-efficacy. Melissa again claimed, "I've always known I'm not good at science, but astronomy I thought might be different," and added, "I guess it's kind of made me not like science even more." Melissa was again asked to describe her science abilities, to which she replied, "Not good. Science is not my thing." Her response indicated that Melissa's astronomy self-efficacy had impacted her science self-efficacy.

When it came to the laboratory assignments, Melissa still claimed to have the same feelings as she had previously, but the test anxiety that had disappeared during the second interview reappeared during the third. "So I mean the lab part isn't really that hard it's just the tests that I don't do well on," Melissa said when referring to her experiences. Even though Melissa claimed, "As I was studying I thought I was going to do really good on it (the exam)," Melissa's performance was not what she expected, and her self-efficacy was corrected.

Melissa placed as much emphasis on vicarious experiences and verbal support during the third interview as she had during the second. Melissa again mentioned the "helpfulness" of her teaching assistant, and when asked what she would keep about the astronomy laboratory, Melissa replied, "I guess I would keep the TA." Likewise, Melissa mentioned how having a laboratory partner helped during the class, but only rated the importance a six out of ten. When she was asked to elaborate on her rating, Melissa replied, "It's nice to have a lab partner because you help each other out if one person doesn't understand and the other one does. Then again, there's always the TA that will help you and stuff." Melissa's response reflected her self-efficacy beliefs about the laboratory assignments but also revealed her most influential sources of those beliefs. Melissa also mentioned that she was, "usually one of the last ones out" of the laboratory classroom, and "Everybody else is kind of like running for it." Melissa's observations of the time it takes her classmates to finish the laboratory assignments indicates that she was at least partially dependent upon that comparison as part of her self-efficacy information.

With the change in self-efficacy beliefs and the return of Melissa's test anxiety, Melissa's attributions seemed to shift toward task difficulty more than anything else. Melissa mentioned on several occasions that she found the laboratory assignments “not really hard” and “straightforward.” This choice of words indicated that Melissa attributed her success not to her ability or the amount of effort she exerts, but to the ease of the task. The emphasis that Melissa previously placed on her own efforts was diminished during the third interview.

The result of the task completion exercise reflected Melissa’s correction in self-efficacy beliefs over the course of the semester. Melissa hesitated to answer questions that were given to her during the task completion. Questions were often responded to with words such as “uh,” “um,” and “I guess,” followed by a response that ended in a question rather than in a definitive response. What was most interesting about the comparison between Melissa’s interview responses and her task response was that the task of examining phases of the Earth and Moon as viewed from an outside vantage point was based on the phases of the moon lab in which Melissa claimed to be the most comfortable and confident.

Melissa overestimated her self-efficacy when it came to understanding the phases of the moon just as she had with her performance on her examinations. Melissa claimed that she found the laboratory assignment “interesting and easy,” and later stated “I guess the lunar phases is the one that I understood the most.” The results of the task completion exercise indicated that Melissa may derive more of her self-efficacy on vicarious sources of information than previously suspected based on the interview data.

8. Sarah

Sarah is a White female who was nineteen years old and in her second semester of her freshman year when the interviews took place. Sarah had taken three science classes in high school, and while each of those classes had laboratory exercises associated with them, none of them had a separate laboratory class. In the previous college semester before the interviews took place, Sarah had taken a non-laboratory science course.

Sarah was an anomaly among the subjects in this study because she exhibited high science self-efficacy. When she described her high school science courses, Sarah claimed, “I did well in them, except chemistry I had a little bit of trouble but I think it had to do with the teacher.” Sarah added, “I think if I applied myself I would be able to handle any of the subjects fine.” Right away, Sarah seemed to recognize the connection between effort and success in a subject. Sarah’s recognition of effort was further iterated when she said, “I don’t think that I have any real problems with doing it, as long as I have the book and everything I can read and learn it fine.” Sarah had no problem believing that she could understand a subject as long as she put forth the effort.

From the onset of the first interview, Sarah’s astronomy self-efficacy reflected her general science self-efficacy. When she was asked if she was having any trouble with the astronomy class, Sarah replied, “I haven’t had any trouble really so far in this semester with astronomy. Everything’s pretty straightforward.” Sarah’s high self-efficacy was also reflected when she was asked what grade she expected in the course. Unlike many of the other subjects, Sarah responded, “an A,” without any hesitation whatsoever. Another example of Sarah’s confidence in the astronomy course came when she was asked a follow up question about her expectations. Sarah referred to the astronomy course as “an entry level course,” saying, “I figured as long as you do the work and the reading you should be able, it shouldn't be too much of a struggle." Sarah's words suggested that even if the course were more difficult than she expected, she would still have confidence in her ability to succeed.

The main source of Sarah's self-efficacy information came from authentic experiences. There were several instances where Sarah discussed how the laboratory assignments contributed to her knowledge. One of the instances occurred when Sarah talked about the celestial sphere lab, "It definitely helped you visualize and get a concept of what's actually happening." Sarah's comments suggested that a visualization tool improved her understanding of the concepts being covered. Another example that Sarah cited as helping her was the laboratory assignment about the phases of the moon. According to Sarah, "it helped to understand how that works, and the different views," suggesting the 'hands-on' experience enabled her understanding. Like many of the subjects, Sarah also gained self-efficacy information from her own performance in the laboratory class. Sarah finding that she was not having too much trouble with any of the assignments reinforced her strong self-efficacy beliefs. Furthermore, Sarah's efforts in studying for the examination resulted in her achieving a grade of an 'A,' which was viewed as a success. According to Sarah, "I studied hard… so I felt really confident going into it." Sarah's success in her performance also reinforced her self-efficacy beliefs.

The strongest attribution that came through Sarah's responses during the first interview was that of effort. Sarah made reference to not only her effort in the astronomy course, but also to her confidence that her effort would enable her success. The discussion above about Sarah's viewpoint of the astronomy class as 'entry level' is a prime example of Sarah's confidence in her efforts. Sarah saying, "I figured as long as you do the work and the reading you should be able, it shouldn't be too much of a struggle," suggested that she is not overly concerned with performing well in the astronomy course. Likewise, when Sarah said, "I like how… there is a chance to get a lot of points not just from tests," she hinted to her ability to gain 'points' from her efforts in the class. Another example of Sarah's strong beliefs in her efforts was when she discussed her attendance in the class, "I go to all of the lectures and discussions so I don't' miss any of the chances to get the information." Sarah's strong attendance record reinforced her beliefs that her efforts will lead to success.

While Sarah's effort attribution appeared strong, she also seemed to exhibit other attributions for her success in the astronomy course. As discussed above, on multiple occasions Sarah relayed her viewpoints about the difficulty of the astronomy course and the laboratory assignments. By viewing the course as 'not too difficult,' and finding that she does not have much difficulty with the subject matter, Sarah suggested that she attributed part of her success to the task difficulty. In comparison, however, the difficulty of the subject matter was a much weaker attribution than Sarah's effort. Another attribution that played a role in Sarah's success was that of interest in the subject. There were several instances where Sarah discussed finding astronomy 'interesting.' Because of her interest, Sarah said, "I'm more motivated to do the readings on schedule." Having the interest in the course material made it easier for Sarah to put forth her best effort in the course.

Sarah's self-efficacy beliefs did not change between the first and second interviews. Sarah claimed during the second interview, "I'd say my confidence is pretty much the same." The data from the second interview seem to support Sarah's claim. For example, Sarah referred to the material in the laboratory assignments as being 'simplified' and said, "I think that they're not too challenging." In a similar fashion, Sarah makes several statements about the laboratory assignments being "fair," "simple," and not "difficult." Sarah responded to the question about her grade expectation with the same amount of confidence in the second interview as she had with the first. In both cases, Sarah responded with a firm "an A" response. Furthermore, when Sarah was asked how she believed she would perform if given a laboratory assignment to complete on the spot, Sarah responded by saying "pretty well as long as there are directions explaining how to do it." The overwhelming amount of evidence suggested that nothing in the course had caused her to change her self-efficacy beliefs.

Part of the reason Sarah's self-efficacy beliefs remained so strong between the first and second interviews may have to do with her self-efficacy sources of information. As with the first interview, Sarah relied on her own authentic experiences during the second interview to make self-efficacy judgments. Sarah referred to the usefulness of her laboratory experiences when she said, "it was so cool to be able to do it ourself and see how it works." Sarah also referred to one of the laboratory assignments as "useful in demonstrating the concept." An additional part of Sarah's authentic experiences was her performance on the laboratory assignments. When she was asked how she was doing in on her laboratory assignments, Sarah responded by saying, "well, pretty good. I've gotten almost full credit on all of my labs. One point off here and there but nothing major." Sarah's continued success on her assignment undoubtedly added to her high self-efficacy beliefs.

While Sarah mainly relied on authentic experiences for her source of self-efficacy information, a small part of Sarah's beliefs may also have come from emotional arousal. In the first interview, Sarah indicated that she had an 'interest' in the subject of astronomy. That interest provided the motivation that Sarah needed to exert effort in the course. During the second interview, Sarah mentioned her interest in astronomy on several occasions, suggesting that the interest not only provided motivation, but also added to her self-efficacy beliefs. For example, when she was asked if she would take another astronomy laboratory course, Sarah replied, "I'd say fairly likely because I find this course very interesting." Sarah responded when she was asked to elaborate with, "Just, learning about all the mysteries of space and stuff. Cause I had no idea about any of it beforehand, so it's all fascinating to me." It was witnessed with other subjects that an interest, or lack thereof, was often related to the success that was achieved in the course. Those who had more interest remained attentive and were more likely to exert more effort than those who had less.

Unlike those who exhibited low astronomy self-efficacy, Sarah derived very little information about her self-efficacy from vicarious experiences or verbal support. While Sarah referred to her teaching assistant as "helpful," she did not seem to rely very heavily on her teaching assistant for support through the course material. This was demonstrated by Sarah's comment, "sometimes I have to ask questions, but my TA's fair, and she's always helpful, and I'm able to figure (the laboratory assignments) out." Similarly, the only time Sarah referred to her classmate's understanding was when she was directly asked. Other than being asked, Sarah did not once compare herself to her classmates.

Sarah's attributions did not seem to change in between the first and second interviews. The data from the first interview suggested that Sarah relied heavily on her efforts to perform well in the astronomy course, and the data from the second interview agree. Sarah referred to her strategy when she discussed the course difficulty, "I do think that the second half of the course is a little bit more difficult," she said, and added, "it requires a little more studying to understand the concepts." Even though Sarah recognized a change in the difficulty level of the course material, she remained positive of her own success, merely adjusting her efforts toward the course. When she was asked about the amount of effort she was exerting toward the class, Sarah responded, "I'd say and average amount of effort, but when it comes to the exams, I study a lot." Sarah's response suggested that she adjusted her efforts depending upon her perception of the difficulty of the assignment, a coping mechanism that has most likely added to her success.

The results of the third interview indicate that the Sarah's self-efficacy beliefs were strengthened by the end of the semester. Sarah claimed to have an increased confidence, she said, "I've become more confident because I've continued to do well in the class." Sarah's words not only spoke to her self-efficacy beliefs, but also revealed the primary source of self-efficacy information. Sarah's increased self-efficacy was also evident when she discusses her opinion of the course material. According to Sarah, "It's not that difficult to get the concepts, you just listen to the explanation the TA gives, and read the lab, the directions, and it's pretty easy."

Similarly, when Sarah was asked what she would change about the laboratory course, she replied, "I didn't find that many issues with it." Sarah's astronomy self-efficacy beliefs echoed her general science beliefs. Sarah was asked to describe her science abilities, to which she replied, "I'd say that I have a good ability at science… I have a good understanding of concepts, if I need to, if I study it, I can." Sarah's astronomy and general science self-efficacy beliefs seemed to parallel to one another. Sarah admitted during the first interview that she believed she would perform well in science if she applied herself, which is precisely the same way she behaved in the astronomy course.

As with the previous two interviews, the third interview revealed that Sarah's primary source of self-efficacy information were her authentic experiences. Sarah's continued success in the course had increased her astronomy self-efficacy. Furthermore, when she discussed the laboratory assignments, Sarah said, "it's helped me understand some of the concepts more." Sarah also claimed that if she would prefer taking the course with the laboratory, because as she says, "it's doing the hands-on activities makes it interesting." The emphasis that Sarah previously placed on task difficulty seemed slightly diminished in the third interview. While she referred to the difficulty of the course material in the second interview, Sarah rarely discussed the issue in the third. On the other hand, Sarah's interest in the course remained the same, suggesting that she still attributed some of her success to her sustained interest.

Despite Sarah's claims in the first interview that she was confident of her success in the astronomy course, the response she gave during the task completion activity was different. When she was asked how confident she was that she would be able to answer the questions during the task correctly, Sarah replied, "I'd say moderately confident." Sarah's confidence response was supported through her responses for the rest of the task completion activity. While several questions were answered with a confident "yes," Sarah answered other task questions hesitantly. However, the questions that Sarah answered with confidence occurred more often than those with which Sarah exhibited difficulty. Sarah's confidence in her responses to the task activity seems to support her responses to the interview questions regarding her confidence. While Sarah repeatedly referred to the astronomy course as "easy" and "entry level," she recognized that she needed to put forth effort if the course material became more difficult. This was the same mechanism that appeared to be in place during the task completion activity.

Table 7: Summary of Interview Results by Subject

Subject	Main Self-efficacy Sources	Main Attributions	Task Performance/ Confidence
Rebecca	Vicarious experiences	Ability, blame, prior knowledge	9%/low
Robert	Vicarious experiences	Interest, task difficulty	91%/moderate
Kristen	Verbal support, vicarious experiences	Effort, task difficulty	27%/low
Samantha	Verbal support	Interest, task difficulty	73%/low
Carrie	Verbal support, vicarious experiences	Ability, prior knowledge	45%/low
Emily	Authentic, vicarious experiences	Effort	73%/moderate
Melissa	Verbal support, vicarious experiences	Task difficulty	36%/low
Sarah	Authentic experiences	Effort	82%/moderate

Chapter 6: Discussion

The qualitative data from the interviews conducted over the course of the Spring 2005 semester provided many insights into the relationship between laboratory instruction and student self-efficacy beliefs. While some of these results were supported previous findings regarding self-efficacy reported in the literature, some of the results were different, and offer room for further study.

Each of the interview participants had varying degrees of self-efficacy, and collectively the group displayed all three possible scenarios of self-efficacy judgments. Those learners that underestimated their self-efficacy beliefs tended to display avoidance behavior typical of those that have low self-efficacy (Alderman, 2003). Similarly, those learners who underestimated their self-efficacy exhibited poorer coping skills than those with higher initial self-efficacy. Those learners who overestimated their self-efficacy initially found themselves faced with a situation of failure, past or present, where they had to re-evaluate their self-efficacy judgments. Two learners of this study judged their abilities correctly, thus their self-efficacy beliefs changed the least of all of the interview participants over the course of the semester.

The results of the interview indicate that the astronomy laboratory environment provided an opportunity for all sources of self-efficacy information to be drawn upon. Among the reasons cited by the participants for the laboratory being important was that of the "hands-on" experience, the existence of partners upon which the learners relied, and the opportunity the laboratory experience provides for interaction with peers and the teaching assistant. One of the most important sources of self-efficacy information among all of the participants was vicarious experiences. This result is not surprising, considering that an individual lacking prior experience with a situation will rely heavily on vicarious experience for self-efficacy input (Bandura, 1986). Prior experience with astronomy was lacking with all of the learners, and prior experience with a college-level laboratory environment was lacking with six out of the eight learners in this study.

Although the attributions for each of the learners varied widely, there were several attributions that appeared repeatedly throughout the semester. Many students (seven out of eight interview subjects), believed that the astronomy course would be easy because it was not like their prior experiences. The attribution of task difficulty was used by the learners as a source of both positive and negative self-efficacy judgments. Those learners thought the course would be easy but struggled had decreased self-efficacy, while those who found the course moderately difficult but did well had increased self-efficacy. Most learners of this study indicated that they were not "good" at science, which was expected given that they enrolled in an astronomy course for non-science majors.

One of the more surprising findings of this study was that many students attributed their success in the astronomy course to having an initial interest in the topic. Those learners who indicated that they had an innate interest in the course material also found that they had an easier time learning the material. Those learners who found the course material "dull" or "boring" had a harder time staying motivated to study for the course. That interest (or lack thereof) enabled the students to work harder and put forth more effort toward learning the course material, which ultimately resulted in higher self-efficacy.

Despite the initial self-efficacy beliefs of the learners, all learners indicated that they had an increase in their self-efficacy beliefs about the astronomy course at the end of the semester. A majority of the learners attributed their increased self-efficacy to having "prior knowledge" about the course. This prior knowledge came in the form of familiarity not only with the course content, but also with the performance expectations for the course. Even though the learners indicated an increased self-efficacy in the astronomy course, most learners indicated that their general science self-efficacy remained the same (or in one case, decreased) over the course of the semester. These results support the idea that the construct of self-efficacy is specific, and overarching broad statements regarding self-efficacy cannot be made (Alderman, 2003).

6.1 Quantitative Data Trends

The Astronomy Diagnostic Test was given to measure any change in comprehension over the course of the semester. The members of the Spring 2005 introductory astronomy course who participated in the pre- and post-course ADT 2.0 assessment demonstrated a significant increase in confidence over the course of the semester. This increase has previously been demonstrated with the use of the ADT 2.0 (Deming, 2002). The interview participants provided an insight as to the possible reasons for the increased confidence, which will be discussed later.

Selection criteria for the interview participants required that they did not score above a rating of "3" on their confidence question on the pre-course ADT. Based on the confidence and achievement criteria, it was anticipated that the interview participants would have a lower confidence rating than the rest of the course participants. The results of the t-test indicate, however, that there was no statistical difference between the interview participants' and the class' confidence on the pre-course ADT assessment. These results are surprising considering that performance is typically dictated by self-efficacy beliefs (Bandura, 1993). However, given that the interview participants indicated that they had little prior background knowledge about the subject of astronomy, the relationship between their self-efficacy and performance at the beginning of the semester was most likely a reflection of their prior general science self-efficacy and the exposure they have had to astronomy-related topics.

While the pre-course ADT results indicate there is no difference in self-efficacy beliefs between the interview subjects and the rest of the class, the post-course ADT results suggest that there was no change in the interview subjects' self-efficacy over the course of the semester. A comparison between the interview subjects' pre-course and post-course confidence results reveal that there is no statistical significance between the pre-course and post-course results. The post-course ADT results show a statistically significant difference between the interview subjects' and the class' confidence. Given the pre-course confidence results and the within-subject confidence comparison results, the post-course confidence results suggest the non-interview participants of the astronomy course had a greater increase in confidence than the interview participants. As will be discussed later, the quantitative and qualitative results regarding the interview participants' self-efficacy agree.

Previous publications regarding the ADT suggest that there are discrepancies in performance between males and females, thus the quantitative results of this study were disaggregated so that comparisons could be made between genders (Deming, 2002). The results of this study indicate that men scored significantly higher with a mean of 7.52 (corresponding to 35%) than women with a mean score of 5.76 (corresponding to 27%). These data roughly agree with the ADT National Project results of 38% for men and 27% for women. The post-course achievement data are also statistically significantly different, with men scoring a mean of 13.38 (corresponding to 63.7%) and women scoring a mean of 11.39 (corresponding to 54.2%). The results of this study indicate that the subjects of this study attained a greater mean increase than the results of the ADT National Project. The results of the ADT National Project cite post-course achievement averages of 53.7% and 41.5% for men and women, respectively. While the ADT National Project results and the results of this study are not statistically compared, similar patterns of gender achievement gaps appear in both studies. Despite gender discrepancies exist between the male and female pre-course and post-course achievement results, both genders displayed significant increases in achievement between the pre-course and post-course assessments.

The results of the comparisons of confidence between genders suggest that males are initially more confident in their science abilities than females. The pre-course assessment male mean was 2.72, while the female mean was 2.27, suggesting an initial discrepancy in confidences between the genders. Again, these results parallel the results of the ADT National Project. However, the difference between the male and female confidence scores in the post-course assessment is not statistically significant, suggesting no difference at the end of the semester. The reason for the lack of statistical difference in confidence between genders at the end of the semester is not clear.

6.2 Self-efficacy Estimations

Predicting change in self-efficacy with continued instruction is not a straightforward task. The learners/participants involved in this study, while varied in their self-efficacy beliefs, loosely defined three general trends in change in self-efficacy over the course of the semester. Each trend depended upon initial self-efficacy beliefs and the learners' individual responses to their environment.

6.2.1 Underestimation of Self-efficacy Beliefs

Rebecca, Samantha, and Emily all claimed that they were not confident in their ability to be successful in the astronomy course. Their low self-efficacy beliefs became apparent when they discussed their feelings about taking the astronomy course. All three women exhibited avoidance behavior, with Rebecca and Samantha specifically toward the astronomy class. Both women described their beliefs about astronomy being easy as a result of it being labeled "for non-science majors." Emily's avoidance behavior was slightly different, as she described not taking a science course if she was not required to do so. The difference between the three women's self-efficacy beliefs in the beginning of the semester was mainly in their expression of wanting to avoid the astronomy class. While Rebecca and Samantha wanted to directly avoid the astronomy class altogether, Emily expressed that she merely wanted to avoid any science class. This difference may explain the enlarged gap in the women's self-efficacy beliefs toward the middle of the semester.

Rebecca, Samantha, and Emily were grouped together for the purpose of this analysis because they all exhibited increased astronomy self-efficacy between the first and second interviews. While the three women of this group appeared to have increased self-efficacy from the first interview, they expressed their self-efficacy in very different ways. At first glance, it appeared that Rebecca's self-efficacy actually decreased between the first and second interviews, especially when she made the claim that she was less confident. Upon further examination however, Rebecca's comments revealed that she was more comfortable with the course material than she allowed herself to believe. Rebecca's comments such as, "I think I'm doing pretty good," and "I think I can do them a little bit better, on my own," suggest that she felt more comfortable with her ability to succeed in the course. Samantha's increased self-efficacy was also displayed through her responses during the second interview. Despite not finding the course interesting enough to put forth effort, Samantha claims, "they grade pretty easy anyway, so I don't try too hard," and that she found some of the laboratory assignments "pretty easy."

Emily's self-efficacy had also increased between the first and second interviews, but in her case, Emily exhibited much higher self-efficacy beliefs than either Rebecca or Samantha. When she was asked where she would rank her understanding as compared to her classmates, Emily replied, "in the top ten percent-ish." Emily's self-efficacy beliefs were further supported through comments such as, "I definitely have learned stuff," and referring to the laboratory assignments as "do-able." In contrast to Emily, both Rebecca and Samantha placed their astronomy understanding below average as compared to their classmates'.

During the final interview, all three women expressed that their astronomy self-efficacy had continued to increase since the beginning of the semester. The main reason these three learners gave for their increased self-efficacy was the familiarity they all had with the course material. While none of the women considered themselves 'good' at science in general, all of them indicated that they are confident in their performance in the astronomy class, albeit not on the same level. Emily exhibited the highest self-efficacy of the three women, which is not unexpected considering that she had the highest self-efficacy at the beginning of the semester. Emily said that she, "can like actually sit down and explain… certain aspects of the universe," indicating that she felt familiar enough with the material to relay it to other people. In the middle was Samantha, who thought, "most of the stuff is pretty easy," and had an increased self-efficacy because she "was mostly just nervous because (she) thought the tests were going to be really hard." Finally, although she exhibited lower self-efficacy than the other learners of this group, Rebecca's self-efficacy increased along with her own recognition that she underestimates her abilities. Rebecca's recognition of her underestimated abilities comes out when she says, "in all honesty I'm probably better at science that I um, like wanna allow myself to be."

6.2.2 Overestimation of Self-efficacy Beliefs

It was previously discussed that an overestimation of self-efficacy beliefs leads to a perceived failure and a new assessment of self-efficacy beliefs. Three of the learners in this study went through such self-efficacy adjustments as a result of their initial overestimation. Robert, Kristen, and Melissa all indicated during the first interview that they found the astronomy course ‘easy.’ Furthermore, each of the learners responded with confidence when they claimed that they would get a good grade in the course. Robert claimed that he was “doing fine” in the astronomy course, and that he enrolled in the course because it was “easy.” Kristen and Melissa discussed the astronomy course in a similar manner. Kristen explained that she heard that, “it was like not hard to get a B in the class,” while Melissa claimed, “how hard can it be to learn about the stars and the planet?” However, each of the learners’ self-efficacies changed by the second interview.

Each of the learners in this trend indicated that their self-efficacy had changed as a result of a particular experience in the astronomy class. Kristen and Melissa both faced a reassessment of their self-efficacy beliefs when they received their grade for the first examination. The reaction of both women suggested that they initially overestimated their self-efficacy. Melissa claimed that she “was feeling confident at first… until I got my first test back and it wasn’t very good.” Similarly, Kristen said that she was “concerned” about her grade after her first examination, and that she “took it for granted that it was going to be like an easy A.” Both Kristen and Melissa realized that they would need to exert more effort toward the class to raise their grade.

While Kristen and Melissa’s self-efficacy reassessment reportedlycame as a result of their performance on a test, Robert’s reassessment was a result of him encountering subject matter with which he previously had trouble. Robert initially thought of the astronomy course material as “easy,” and claimed to have “no trouble” during the first interview. During the second interview however, Robert changed his responses. While he still found most of the material "easy," Robert realized that some of the course material would give him more difficulty than he originally anticipated.

The results of the third interview revealed that while all three learners in this trend experienced a reassessment of self-efficacy beliefs during the course of the semester, two of the three learners reassessed their self-efficacy correctly, and one incorrectly. All three learners admitted to feeling more confident about their astronomy performance in between the first and second astronomy examinations. However, Robert and Kristen assessed their self-efficacy correctly, while Melissa again made an overestimation. During the second interview, Melissa felt that she "would do a lot better on my test just because I know what to expect now," but during the third, she claimed, "I did feel a lot better until I took my second exam, and then I didn't do well on it at all." Melissa's overestimation gave her a false sense of confidence before the second examination, and upon the results, her confidence had decreased and was "back to where (it) was."

In contrast, Robert and Kristen apparently made realistic reassessments of their self-efficacy. Both Robert and Kristen indicated that their self-efficacy increased by the end of the semester. In Kristen's case, her self-efficacy increased as a result of "putting more work into the class," while in Robert's, he "I go over it (the course material) with a friend… and then… I generally know everything and I go into the test with confidence." An important feature to note about both Robert and Kristen is that their increased self-efficacy was a result of their realization that they needed to increase their effort toward the astronomy course. On the other hand, Melissa's effort toward the astronomy course seemed to remain at a constant level between the second and third interviews.

6.2.3 Affirmation of Initial Self-efficacy Beliefs

Both of the learners/participants in this group exhibited higher initial self-efficacy beliefs than the other learners of this study. Carrie and Sarah both expressed confidence in their ability to perform well in the astronomy course in the initial interview. Carrie claimed that she would get either an A or a B in the course, while Sarah was firm about her confidence in earning a grade of an A. One of the traits that these women had in common was an initial recognition of their efforts toward a class and the resulting grade. This trait seemed to be lacking, at least initially, in the rest of the learners in this study. Sarah recognized that "as long as you do the work… it shouldn't be too much of a struggle." Likewise, Carrie claims, "when I did my part to pay attention… and make an effort… then I was pretty confident in doing the labs."

The initial self-efficacy judgments that were made by Carrie and Sarah were affirmed by the middle of the semester. Sarah's expectations that she would do well in the class were met, and her confidence remained the same. Carrie's expectations were exceeded, and her increased self-efficacy was apparent when she firmly claimed that she expected a grade of an A in the course. Both women continued to recognize that their effort was required for them to do well in the course. Carrie recognized that completing the extra credit assignments helped her grade, while Sarah recognized that an increase in the difficulty of the course material would require her to increase her effort toward the astronomy class.

By the end of the astronomy course, both Carrie and Sarah exhibited increased self-efficacy, although attributing their successes to different causes. Sarah's increased self-efficacy was attributed to her continued success in the astronomy course while Carrie's was due to becoming familiar with the course material. What set these two learners apart from the rest of the learners at the end of the semester were their realistic views of their own self-efficacy. Carrie recognized that although she did not have extremely high science self-efficacy, she would be able to succeed in the astronomy course as long as she put forth the effort. On the other hand, while Sarah had the highest self-efficacy beliefs of any of the learners, she also recognized the importance of putting forth effort in order to succeed. The resulting success in the astronomy course solidified both Carrie's and Sarah's initial self-efficacy beliefs.

6.3 Self-efficacy Change

There are many different reasons why self-efficacy beliefs can be changed, and as the learners in this study demonstrate, these reasons are dependent upon initial beliefs and the experiences that are most influential to an individual. Despite the overwhelming possible reasons for a change in self-efficacy, the results of this study suggest that students in an introductory astronomy course for non-science majors experience similar reasons for their changes. Each of the experiences had the possibility of having positive or negative effects on the learners' self-efficacy.

6.3.1 Authentic Experiences

A search for the reasons why students reassess their self-efficacy judgments starts with an examination of the sources of self-efficacy information. All of the learners/participants within this study drew at least partially from authentic and vicarious experiences, verbal persuasion, and emotional arousal. One of the authentic experiences that had an influence on the learners' self-efficacy beliefs was that of the "hands-on" experience. Several of the learners cited working with materials in the laboratory as enhancing their learning about a topic. For some, working with a celestial sphere or viewing shadows on a Styrofoam ball helped them "visualize" the concepts that were being taught. This visualization enabled the learners to better grasp the concept and improved their understanding. As a result, the increased understanding increased the learners' self-efficacy. On the other hand, the hands-on experience caused anxiety for some learners, inhibiting them from understanding the concepts and decreasing their self-efficacy.

Another important authentic experience to the learners was the direct feedback they received through the dispersion of grades. Students who experienced an increase in their self-efficacy because of grades experienced repeated success with the course materials. Students received grades on laboratory and homework assignments as well as examinations. Those students who performed well on their laboratory assignments had increased self-efficacy. As mentioned above, some students overestimated their self-efficacy, and a perceived failure on an examination grade caused them to reassess their beliefs. Those students who correctly reassessed their self-efficacy adjusted their expectations and efforts ultimately ended the semester with higher self-efficacy judgments than those who did not.

6.3.2 Vicarious Experiences

Without a doubt, one of the most influential experiences that was cited by the learners in the data was that of having a partner with whom to work on the laboratory assignments. While most of the learners cited their reliance on partners to help them through their work, the learners whose self-efficacy was on the lower end of the spectrum relied much more heavily on their partners to help them through their assignments than those on the higher end of the spectrum. Some of the reasons why such an emphasis was placed on the use of partners included using them as a means to check work, asking partners questions if they got 'stuck,' and using partners as a support mechanism. Many of the learners credited their partner's help for their increased confidence in the astronomy course. Unfortunately, relying on others as a source of self-efficacy information may be just as detrimental to self-efficacy beliefs as it is helpful.

While relying on partners to better understand course material increased the self-efficacy for some learners, other learners' self-efficacy decreased as a result of their perceptions of their classmates' abilities. Some learners refrained from asking their partners questions in an effort to preserve their appearances; questions were not asked for fear that the subject might feel "stupid." Other learners viewed their classmates' performances as a reflection of their own deficiencies. Several learners mentioned that they noted the amount of time it took their classmates to complete a laboratory assignment, which somehow made them feel like they had less understanding because they had yet to finish. Also, some of the learners claimed that they would not want to work with a classmate whom they perceived as having more understanding than they; for fear that their performance would hold their partner back. In these cases, using a classmate's experience in the aforementioned manner was detrimental to the subject's self-efficacy.

6.3.3 Verbal support and blame

For most of the learners/participants, the teaching assistant played an important role in framing self-efficacy beliefs throughout the semester. There were many examples of the learners relying on their teaching assistant for support, either in the form of asking questions, going to the teaching assistant for extra help, or asking the teaching assistant for further explanations. Many of the learners relied on this support and encouragement, and as a result, found that they understood the subject material better. The increased understanding that the learners gained from their teaching assistant added to and increased their self-efficacy beliefs.

On the other hand, there were a few instances where the teaching assistant was blamed by the students for a lack of support. A teaching assistants' accent was used as blame in one instance where a student relied on a partner for help rather than the teaching assistant. Another student decided that her teaching assistant was 'unapproachable,' and as a result, she refrained from asking him questions and relying on him for support. Again, by default, she resorted to relying on her partner for help. Being intimidated by her teaching assistant, this subject felt like she was "stupid" for not being able to understand the information on the laboratory assignments. Yet another student referred to her teaching assistant as "not that good."

Relying on a teaching assistant for support increased self-efficacy for some when the relationship was good, but decreased self-efficacy for others when it lacked.

The learners not only cited sources of self-efficacy judgments as reasons for changing their self-efficacy, but other reasons not necessarily directly related to it. At the end of the semester, several of the learners cited "being in the know" as a reason why their self-efficacy increased. This familiarity with the course material enabled the learners to be aware of their tasks, including the laboratory and homework assignments as well as examination expectations. With the experience of knowing the assignments, some of the learners adjusted their effort accordingly, which enabled them to achieve success in the classroom.

Familiarity of the course material also played a role in decreasing self-efficacy for some students. As discussed previously, some students expected the material to be easier than they found it to be, and as a result, underestimated the amount of effort that was required in order to achieve success. These students were faced with a perceived 'failure,' and were forced to reassess their self-efficacy beliefs. Learners were also indirectly influenced when they anticipated the difficulty of the material only to find it more difficult than they expected. The combination of believing astronomy to be an 'easy' course along with a perceived failure of that course resulted in a decline in self-efficacy beliefs.

6.4 Attribution Changes

As with the prior results of this study, the attributions of the learners in this study varied widely depending upon initial self-efficacy beliefs and individual experiences. Some learners experienced major shifts in attributions while other learners' attributions changed very little. The reasons behind the attribution changes also varied depending upon individual self-efficacy beliefs and individual experiences. In contrast to Alderman's (2003) work, in this study, luck was not identified as an attribution. On the whole, those learners who exhibited higher initial self-efficacy experienced less change in their attribution than those with lower initial self-efficacy.

6.4.1 Expected Attributions

There were several attributions that were expected in the learners based on prior attribution research. Self-efficacy itself is a construct that explains the nature of the belief an individual holds about his or her own abilities, thus it is expected that the learners would have pre-conceived notions about their own scientific abilities. Effort and task difficulty have also been recognized as common attributions, and were expected to be present among the learners of this study. Each of these attributions was indeed present, but not necessarily in the context expected.

Students who enroll in a science course for non-science majors have already decided that for various reasons, science is not a subject they wish to pursue. As predicted, the learners/participants in this study all responded that they do not consider themselves "science" people. As expected, the amount to which learners considered themselves good at science varied with their self-efficacy beliefs. Those learners who had higher self-efficacy ranked themselves average to above average with respect to their classmates' abilities, while those with lower self-efficacy placed themselves on the lower end of scientific understanding. Most learners expressed their belief that scientific understanding is a result of ability rather than learned. For example, Rebecca spoke to the point when she described some of her high school classmates as “science geniuses.” Similarly, Robert rates himself as average because in his words, his classmates “don’t know a lot.” These expressions regarding scientific “ability” suggest that the learners believe scientific understanding is inherent, and is something that they lack.

Learners/participants of this study also attributed their astronomy laboratory performance to the difficulty of the assignments. The students did not meet a general consensus on the difficulty level of the assignments. Some students found the assignments easy, while others found that they struggled to complete them. Each of the students’ self-efficacy beliefs was affected depending upon how the assignments were viewed and the resulting grade on that assignment. In general, those students who had higher self-efficacy and experienced success on lab assignments found the exercises challenging but not impossible to complete, and attributed their success to their ability. On the other hand, those students who had low self-efficacy and experienced success on lab assignments more readily attributed their success to the ease of the exercise rather than their own ability. Several of the students indicated that they enrolled in the astronomy class because they perceived it as “easier” than some of the other science courses available to them, and that would enable them to achieve a good grade in the course. While the students’ avoidant behavior is not a direct attribution at the beginning of the semester, it speaks to their attributions that they would more readily achieve success in an easier course.

One of the most surprising results from the data is the acute disconnect the students have between their effort and their self-efficacy beliefs. Many students recognized throughout the semester that to achieve success, they must first put forth an effort in the class. Despite this recognition, because the students believed in the concept of scientific "ability," the efforts the students made toward the class did not increase, but in some cases *decreased* their self-efficacy. Robert exemplified the effort-self-efficacy disconnect in his comment, "that's the same as it is with anything," suggesting that he expects an improvement in his grades with increased effort, but still considers himself not good at science. One of the cases where effort seemed to decrease self-efficacy was with Melissa. Melissa considered the astronomy course to be "easy," and as a result, put forth little effort toward the class until she failed the first examination. Melissa increased the amount of effort she was putting forth toward the class, but still performed poorly on the second examination. The result of Melissa's performance, along with her belief in the difficulty level of the course, was an overall decrease in her self-efficacy by the end of the semester. The disconnect between effort and increased self-efficacy is most likely a result of an attribution that was unexpected, as revealed by the students.

6.3.2 Unexpected Attributions

The data from the students' interviews revealed several new attributions that have not previously been reported. Prior knowledge about expectations, blame on those in the role of instructors, and interest in the subject were all revealed as attributions that the students held for their successes or failures. A majority, if not all of the students expected the introductory astronomy course to be easy. These expectations came from the description of the class as "for non-science majors" or through hearsay from students who previously enrolled in the class. Some of the students found their expectations met, while others found the course harder than they anticipated. Carrie's case is a prime example of how many of the students attributed their success in the astronomy course to knowing what to expect. In the beginning of the semester, Carrie spoke of her increased confidence because she was aware of how she needed to prepare for the course. Over the course of the semester, Carrie's astronomy self-efficacy increased, and she repeatedly attributed her confidence to "being in the know." This pattern of increased confidence being attributed to knowing what to expect permeated all of the students' interviews. Each and every one of the students at some point during the course of the interview process spoke to knowing "what to expect" or how the homework/laboratory assignments/exams would go.

Also important to the students was the amount of interest they had in the topics taught in the astronomy course. Several of the students spoke about initially enrolling in the astronomy course because they were interested in the topic. Aside from enrolling in the course to fulfill a requirement, Carrie, Sarah, and Emily indicated that they enrolled in the introductory astronomy course because they knew little about the subject, but found it interesting. Emily speaks to the role interest plays in learning when she says "I think anything is easier when you like it." Similarly, Carrie said, "things that… I'll find really fascinating like I'll really grasp." Both of these students iterate the role that interest has in learning, namely that if the subject found a topic interesting, they found it easier to learn. Melissa discussed the other side of the interest spectrum. On several occasions, Melissa mentioned that she does not find the subject of astronomy interesting. As a result, Melissa found the astronomy course difficult. On the other hand, when Melissa found a topic interesting, she found it easier to understand. Kristen also found that she had a hard time staying motivated to work to learn a subject in which she was disinterested.

Most of the students in this study discussed the role that teachers played in their ability to learn a topic. Those students that had good relationships with their teaching assistants had very little difficulty relying on those teaching assistants for help. On the other hand, several students found that they had very little faith in their teaching assistants' abilities to teach. Robert, Rebecca, and Emily each at one point in time during the semester blamed their teaching assistants for their own difficulties with the course material. In each case, blame was used as an excuse why the students had difficulty with course material. While blame was cited as an attribution, it was not as prevalent as any of the other attributions.

6.5 Quantitative – Qualitative Data Comparisons

The results of the quantitative data suggest that the interview students' confidence did not increase over the course of the semester, and the results of the qualitative data agree. Each of the interviewees indicated that their science self-efficacy remained unchanged between the first and last interview. However, the quantitative data suggest that the rest of the course members had an increase in overall science self-efficacy. Given the performance discrepancies between the interview students and the rest of the class, it is likely that the interview students' performance affected their science self-efficacy judgments. Interview data also support this contention. Several of the interview students had a negative change in science self-efficacy as a direct result of their performance in the introductory astronomy course. When coupled with the attributional beliefs of the students detected by application of the qualitative methods, this relationship becomes even clearer. It is likely that the attributional belief that the astronomy course should be "easy" and the realization of a failure on an examination combined to have a negative impact on some of the students' self-efficacy beliefs. Other students attributed their good performance to the difficulty of the level of the course rather than their own capabilities, which can account for the lack of improvement of self-efficacy beliefs.

6.6 Implications

One of the most significant results of this study is the role that attributions play on self-efficacy beliefs. Many of the students enrolling in an introductory astronomy course for non-science majors already have the belief that they lack scientific abilities, and that belief initially impacts their decision to enroll in the astronomy course. Given that several of the students in this study indicated that their primary reason for enrolling in the astronomy course was because of their belief that it will be "easy," it is likely that many more students enrolling in an introductory astronomy course hold the same belief. Instructors of introductory astronomy courses for non-science majors should examine and address these initial beliefs before their students' performance can further impact their own self-efficacy. It is also recommended that introductory astronomy instructors use a diagnostic test such as the Astronomy Diagnostic Test 2.0 in order to get an initial assessment of their students' self-efficacy beliefs as well as pre-course knowledge. Addressing initial self-efficacy and attributions has been previously recommended (Alderman, 2003).

Given the role attributions play on self-efficacy beliefs, it is also recommended that introductory astronomy laboratory instructors address the role of expended effort towards success in the classroom. There was a general disconnect for the students in this study with regard to the amount of effort they expended in the classroom and their ability to understand and “do” science. Having an awareness of their students’ attributions will enable introductory astronomy instructors to address the need to be persistent with studies, and perhaps ultimately be able to address their students’ general science self-efficacy.

The results of this study suggest that the introductory astronomy laboratory course provides an opportunity for students to have the opportunity to gather self-efficacy information through the laboratory experience. It is therefore suggested that laboratory instructors take advantage of this opportunity to address their students’ self-efficacy beliefs through the increased use of vicarious experiences in the laboratory environment. Vicarious experiences that can be easily incorporated into the astronomy laboratory include student modeling, where students learn from one another though an “expert” classmate, and increased student cooperation during laboratory assignments. It is recommended that students be provided an opportunity to interact with one another on a regular basis. Most laboratory assignments can be adapted to allow partner or group activities surrounding the observation, collection, and analysis of data.

Table 8: Summary of Research Implications

Address student initial attributions about the difficulty of the introductory astronomy course in order to prevent negative self-efficacy impact.
Emphasize the role of effort students expend toward the introductory astronomy course in their success.
Increase the opportunity for students to engage in vicarious experiences in the laboratory to address student self-efficacy beliefs.
Increase student interest in astronomy topics through the use of current astronomy research and missions to boost student learning motivation.

6.7 Limitations

The results of this study indicate that self-efficacy is an important construct in identifying student behavior in the introductory astronomy classroom for non-science majors. However, the results of this study can only be applicable in certain scenarios. First, this study was designed to examine a single introductory astronomy class with laboratory for non-science majors in a large university. Subjects in this study were only followed for a single semester, thus long-term effects of the laboratory environment on self-efficacy beliefs are not addressed. Second, the subjects that participated in the interviews were identified as having low initial self-efficacy. Therefore, the results of this study may not be applicable to those students in an introductory astronomy laboratory course for non-science majors who have high self-efficacy. While male to female comparisons were made for the quantitative data, the male to female qualitative data were insufficient to make meaningful comparisons in self-efficacy beliefs. Finally, all of the interview subjects in this study were White, and not necessarily representative of the average student body of an introductory astronomy laboratory class for non-science majors.

6.8 Recommended future research

The scope of this study posed interesting questions that were previously unanswered in the astronomy education research realm. However, as the research questions were addressed, new questions were posed that were beyond the scope of this study. For example, how do the results for students with high initial self-efficacy compare to the results of this study? One of the observations that arose from this study was that a larger proportion of females than males responded to the opportunity to earn extra credit by participating in this study. Why was there a discrepancy in gender response and is it related to discrepancies in initial self-efficacy beliefs, as quantitative data suggest? Several questions surrounded the research process itself. What were the effects (if any) of the interview process on the subjects themselves? Did the interview process raise self-awareness of self-efficacy beliefs and thus have an effect on the participants? Since this study only encompassed a single semester, the long-term effects of the astronomy laboratory on self-efficacy beliefs could not be addressed. What are these effects? These questions leave room for further investigation into the role of the astronomy laboratory on student self-efficacy beliefs.

Appendices

Appendix A: Astronomy Diagnostic Test 2.0

1. As seen from your current location, when will an upright flagpole cast no shadow because the Sun is directly above the flagpole?

A. Every day at noon.
B. Only on the first day of summer.
C. Only on the first day of winter.
D. On both the first days of spring and fall.
E. Never from your current location.

2. When the Moon appears to completely cover the Sun (an eclipse), the Moon must be at which phase?

A. Full
B. New
C. First quarter
D. Last quarter
E. At no particular phase

3. Imagine that you are building a scale model of the Earth and the Moon. You are going to use a 12-inch basketball to represent the Earth and a 3-inch tennis ball to represent the Moon. To maintain the proper distance scale, about how far from the surface of the basketball should the tennis ball be placed?

A. 4 inches (1/3 foot)
B. 6 inches (1/2 foot)
C. 36 inches (3 feet)
D. 30 feet
E. 300 feet

4. You have two balls of equal size and smoothness, and you can ignore air resistance. One is heavy, the other much lighter. You hold one in each hand at the same height above the ground. You release them at the same time. What will happen?

A. The heavier one will hit the ground first.
B. They will hit the ground at the same time.
C. The lighter one will hit the ground first.

5. How does the speed of radio waves compare to the speed of visible light?

A. Radio waves are much slower.
B. They both travel at the same speed.

C. Radio waves are much faster.

6. Astronauts inside the Space Shuttle float around as it orbits the Earth because
A. there is no gravity in space.
B. they are falling in the same way as the Space Shuttle.
C. they are above the Earth's atmosphere.
D. there is less gravity inside the Space Shuttle.
E. more than one of the above.

7. Imagine that the Earth's orbit were changed to be a perfect circle about the Sun so that the distance to the Sun never changed. How would this affect the seasons?

A. We would no longer experience a difference between the seasons.
B. We would still experience seasons, but the difference would be much LESS noticeable.
C. We would still experience seasons, but the difference would be much MORE noticeable.
D. We would continue to experience seasons in the same way we do now.

8. Where does the Sun's energy come from?

A. The combining of light elements into heavier elements
B. The breaking apart of heavy elements into lighter ones
C. The glow from molten rocks
D. Heat left over from the Big Bang

9. On about September 22, the Sun sets directly to the west as shown on the diagram below. Where would the Sun appear to set two weeks later?

A. Farther south
B. In the same place
C. Farther north

10. If you could see stars during the day, this is what the sky would look like at noon on a given day. The Sun is near the stars of the constellation Gemini. Near which constellation would you expect the Sun to be located at sunset?

A. Leo
B. Cancer
C. Gemini
D. Taurus
E. Pisces

11. Compared to the distance to the Moon, how far away is the Space Shuttle (when in space) from the Earth?

A. Very close to the Earth
B. About half way to the Moon
C. Very close to the Moon
D. About twice as far as the Moon

12. As viewed from our location, the stars of the Big Dipper can be connected with imaginary lines to form the shape of a pot with a curved handle. To where would you have to travel to first observe a considerable change in the shape formed by these stars?

A. Across the country
B. A distant star
D. Moon
E. Pluto
C. Europe

13. Which of the following lists is correctly arranged in order of closest-to-most-distant from the Earth?

A. Stars, Moon, Sun, Pluto
B. Sun, Moon, Pluto, stars
C. Moon, Sun, Pluto, stars
D. Moon, Sun, stars, Pluto
E. Moon, Pluto, Sun, stars

14. Which of the following would make you weigh half as much as you do right now?

A. Take away half of the Earth's atmosphere.
B. Double the distance between the Sun and the Earth.
C. Make the Earth spin half as fast.
D. Take away half of the Earth's mass.
E. More than one of the above

15. A person is reading a newspaper while standing 5 feet away from a table that has on it an unshaded 100-watt light bulb. Imagine that the table were moved to a distance of 10 feet. How many light bulbs in total would have to be placed on the table to light up the newspaper to the same amount of brightness as before?

A. One bulb.
B. Two bulbs.
C. Three bulbs.
D. Four bulbs.
E. More than four bulbs.

16. According to modern ideas and observations, what can be said about the location of the center of the Universe?

A. The Earth is at the center.
B. The Sun is at the center.
C. The Milky Way Galaxy is at the center.
D. An unknown, distant galaxy is at the center.
E. The Universe does not have a center.

17. The hottest stars are what color?

A. Blue
B. Orange
C. Red
D. White
E. Yellow

18. The diagram below shows the Earth and Sun as well as five different possible positions for the Moon. Which position of the Moon would cause it to appear like the picture at right when viewed from Earth?

19. You observe a full Moon rising in the east. How will it appear in six hours?

20. With your arm held straight, your thumb is just wide enough to cover up the Sun. If you were on Saturn, which is 10 times farther from the Sun than the Earth is, what object could you use to just cover up the Sun?

A. Your wrist
B. Your thumb
C. A pencil
D. A strand of spaghetti
E. A hair

21. Global warming is thought to be caused by the

A. destruction of the ozone layer.
B. trapping of heat by nitrogen.
C. addition of carbon dioxide.

22. In general, how confident are you that your answers to this survey are correct?

A. Not at all confident (just guessing)
B. Not very confident
C. Not sure
D. Confident
E. Very confident

23. What is your college major (or current area of interest if undecided)?

A. Business
B. Education
C. Humanities, Social Sciences, or the Arts
D. Science, Engineering, or Architecture
E. Other

24. What was the last math class you completed prior to taking this course?

A. Algebra
B. Trigonometry
C. Geometry
D. Pre-Calculus
E. Calculus

25. What is your age?
A. 0-20 years old
B. 21-23 years old
C. 24-30 years old
D. 31 or older
E. Decline to answer

26. Which best describes your home community (where you attended high school)?

A. Rural
B. Small town
C. Suburban
D. Urban
E. Not in the USA

27. What is your gender?

A. Female
B. Male
C. Decline to answer

28. Which best describes your ethnic background?

A. African-American
B. Asian-American
C. Native-American
D. Hispanic-American
E. None of the above (see question 29 below)

29. Which best describes your ethnic background?

A. African (not American)
B. Asian (not American)
C. White, non-Hispanic
D. Multicultural
E. None of the above (see question 28 above)

30. How good at math are you?

A. Very poor
B. Poor
C. Average
D. Good
E. Very good

31. How good at science are you?

A. Very poor
B. Poor
C. Average
D. Good
E. Very good

32. Which best describes the level of difficulty you expect/experienced from this course?

A. Extremely difficult for me
B. Difficult for me
C. Unsure
D. Easy for me
E. Very easy for me

33. How many astronomy courses at the college level have you taken?

A. I'm re-taking this course.
B. This is my first college-level astronomy course.
C. This is my second college-level astronomy course.
D. I've completed more than two other college-level astronomy courses.

Appendix B: Subject Interview Protocols

Interview 1: Introduction

Good day. My name is Brooke Carter, and I am a graduate student in the Department of Curriculum and Instruction in the school of Education. I am working on my Masters of Art in Science Education, and I'm here with you today, because you have been selected as one of the participants in my thesis study.

You have indicated on your consent form that you have agreed to be audio taped, which I will now start.

As I have just said, you have been selected as a participant in the study Self-efficacy and the Astronomy Laboratory: an investigatory study. All information that is gathered from this and following interviews and observation sessions will be kept confidential. You will be assigned a pseudonym which will be used from this point forward in order to conceal your identity. This designated pseudonym will be used in any subsequent discussions and publications, and your true identity will be known only to me.

Your pseudonym is (insert pseudonym here).

This interview will be one of three throughout the semester. You will encounter two types of questions in this interview. The first set of questions will be geared toward your educational background. The second set of questions will be geared toward your reaction of the laboratories at this point in the semester. There are no right or wrong answers to these questions. I am simply trying to understand how the laboratory affects your confidence, so please be honest with me. You may decline to answer any questions or to withdrawal from this study at any time, with no repercussions to your course grade.

Part I: Educational background questions

1. Can you list the science courses you have had prior to this course?

2. Which of those classes had a laboratory component?

3. How confident were you about your performance in those laboratory classes?

4. Can you recall your feelings about your science confidence after having taken one of those laboratory classes? What were they?

Part II: Self-efficacy questions

1. What strengths/weaknesses do you believe you have in studying science?

2. Were you apprehensive about taking Astronomy 101? Why/why not?

3. Were you apprehensive about the first laboratory? Why/why not?

4. What is your confidence in successfully completing this course? Is that different from what you first felt coming in to this course?

5. Are there any parts of the laboratory that you believe you are better at than others? What are they?

6. Has the laboratory affected your confidence in successfully completing this course?

7. Do you find yourself working harder in this class as compared to other courses you're taking this semester? Has your effort affected your performance?

8. How would you rate the difficulty of this course compared to other laboratory courses you have taken? Could you explain why?

9. How are you adjusting to the amount of work in this class? Are you finding it more difficult or easier as the course continues?

Interview 2 Questions

How are things going in the laboratory class?

What part of the laboratory are you enjoying the most? Why?

What part of the laboratory are you enjoying the least? Why?

How is your laboratory performance to date?

What grade do you expect from this class?

If I were to give you a laboratory assignment to perform right now, how well do you think you would do? Why?

If you needed to take another science lab course to fulfill your core course credits, how likely would you be to take another astronomy lab course? Why?

Are you more or less confident than you were at the beginning of the semester? Why?

To what do you attribute your confidence in the astronomy laboratory?

How much effort have you been exerting toward this class?

How would you rate your astronomy understanding as compared to those in your laboratory section?

Could you give an example of an activity in the laboratory that stressed you out, why it stressed you out, and what you did to manage the activity?

How would you describe your relationship with your TA?

How would you describe your relationship with your classmates?

How did you feel about the laboratory assignment where you worked on the computers?

Are you finding the laboratory assignments challenging? Why/why not?

Interview 3 Questions

1. Think back to the beginning of the semester. Has your confidence in astronomy 101 changed since our first interview? How and why?

2. If you could change anything about the laboratory (assignments, time restrictions, TAs, etc.), what would you change, and why?

3. What aspect of the laboratory would you keep? Why?

4. What role has your partner(s) played in your understanding of the laboratory assignments?

5. Who do you find helps each other more, you or your partner(s)? Why and how?

6. On a scale of 1 to ten, how important is it for you to work with a partner in the laboratory? Why?

7. Would you prefer to work with someone who has more, less, or the same amount of understanding about the laboratory assignments than you? Why?

8. How hard have you worked to understand the laboratory assignments?

9. How would you describe your science abilities?

10. Are there any parts of the laboratory that you feel you are better at than others? What are they?

11. In your opinion, what is the most difficult part of the laboratory?

12. What is the easiest part of the laboratory?

13. What impact has the laboratory had on your performance in the lecture portion of astronomy 101? Why?

14. If you had to take astronomy 101 again, would you prefer to take the class with or without the laboratory? Why?

15. What proportion of the concepts covered in the laboratory would you say you understand?

16. Has your attendance in the astronomy 101 laboratory affected your opinion of your scientific understanding? Why?

Appendix C: Instructor and Teaching Assistant Protocol

1. How much teaching experience do you have outside of Astronomy 101?

2. How long have you been teaching Astronomy 101?

3. How would you describe your teaching style?

4. Could you describe a typical day in your class?

5. On average, how long do students spend in class on the following:

Answering questions?

Sleeping, goofing off, or other non-class related activities?

6. What is your relationship with your students?

Do you know their names?

How often do you see your students outside of the classroom?

7. How do you handle students with behavioral problems?

8. What is your perception of your students' confidence?

9. How confident are you that after watching a television documentary dealing with some aspect of astronomy, your students could write a summary of its main points?

10. How confident are your students that they will be successful in this astronomy course?

11. How confident would your students be about watching a television documentary dealing with some aspect of astronomy and explaining its main ideas to another person?

12. How often do your students ask for your help in the class?

13. How confident would your students be about listening to a public lecture regarding some astronomy topic and writing a summary of its main points?

14. How confident would your students be about listening to a public lecture regarding some astronomy topic and explaining its main ideas to another person?

15. How much effort to you think your students are putting forth in the laboratory class?

16. Where would you rank this semester's students in the overall astronomy 101 class standings since you've been teaching the course?

17. What percentage of the course material do you think your students understand? Why?

18. How would you rate your teaching abilities?

19. How confident are you that you could explain a difficult concept to one of your students and have them understand it completely?

20. What part of teaching do you enjoy the most? Why?

21. What part of teaching do you enjoy the least? Why?

Appendix D: Task Completion Activity Protocol

Phases of the Earth and Moon

Introduction

Imagine that you are standing on Jupiter's north pole, 5 AUs from the sun, looking at the Earth-Moon system, 1 AU from the sun. Your job, as an astronomer on Jupiter, is to make observations of the Earth and Moon, and describe the positions throughout one Earth year. Assume Jupiter remains at one point in its orbit throughout one Earth year, and answer the following questions. You may use the materials provided to help you with your explanations.

1) What is the maximum amount of illumination the Earth will reach? Is it the same for the moon?

2) Is there a point where the Earth is visible and the moon is not? If so, can you show me where this might occur?

3) Is there a point where the Moon is visible and the Earth is not? If so, can you show me where this might occur?

4) Could you identify where the Earth and Moon are when a lunar eclipse occurs on Earth? A solar eclipse on Earth?

5) Could the Earth-Moon system ever provide a solar eclipse on Jupiter? Why/why not? (Transits)

6) Can you identify the point in Earth's orbit where it appears to be a waxing crescent from your standpoint on Jupiter?

Appendix E: Statistical Test Descriptions

Student's t-test for dependent means

This statistical test is used to test the null hypothesis H_o: $\delta = \mu_1 - \mu_2 = 0$, where δ is the difference between two means μ_1 and μ_2 when dependent samples are used. The null hypothesis is tested by using the mean of the difference scores, standard error of the difference, and the level of significance (α). The level of significance is defined as the probability of rejecting the null hypothesis when it is true.

Student's t-test for independent means

This statistical test is used to test the null hypothesis H_o: $\mu_1 - \mu_2 = 0$, where μ_1 and μ_2 are the means of samples 1 and 2, respectively, when independent samples are used. The null hypothesis is tested by using the sample means and standard error of the means, and the level of significance (α). The level of significance is defined as the probability of rejecting the null hypothesis when it is true. In order to use the student's t-test for independent means, equal variances must be assumed. The Levene's test is used to determine whether the variances of the two samples are equal.

Levene's test for homogeneity of variances

This statistical test is used to determine whether the variances of two samples are equal. If the level of significance on the SPSS output is greater than 0.05, then equal variances are assumed.

Appendix F: Example of Raw Data Transcripts*

Transcript of Interview 2, Subject 5

Tuesday, April 12, 2005

12:25 pm

1248 CSS Building

Interviewer (**I**): See if we can get it to work today. So how are things going in the lab class?

Subject (**S**): Good, good. Very good. Yeah, we did a uh, emission spectrum last class. That was interesting. It was dark in the room, so I almost like fell asleep, but.

I: Oh no.

S: I know. It was good, it worked out well.

I: What part of the lab are you enjoying the most?

S: Um, I like being able to like actually do stuff and like interact with, you know, like people and also like more like hands-on things with like materials instead of just sitting working in the workbook 'cause that gets kind of boring sometimes. But um, when we have things that actually like last lab we, we got to like move around the room and you know, like visit these different like, um, like light spectrums and, and try to figure out what you know, these like three unknown elements by comparing them to like um, chart, or uh yeah, spectrums that we had on piece of paper, so that was kind of cool.

I: What part of the lab do you like the least?

S: Um, huh. Probably like how much information you have to, to record and then after you're done with that you have to answer, analyze and answer questions and by that time you're like really exhausted. So, I don't know. Maybe if, if you had to answer questions kind of as you went along, gathering your data. I guess then that defeats the purpose of analysis afterwards.

I: So the amount of

S: Like the amount of data, in addition, like yeah, the questions that you have to answer in addition to the huge amount of data that you gathered during the two hour period, you know?

I: Okay. How's your lab performance to date?

S: Um, grade wise?

I: Mm hmm.

S: Um yeah, good. Like I've been getting like high scores, think they're out of, well, some I think are out of like twelve. I've been getting like 11, 11 and a halves, twelve. It also helps that we can um, mm, discuss the answers and kind of like talk things out with other members of the class, you feel a little more confident about your train of thought I guess.

I: What grade do you expect from the class?

S: An A. I would say. Right now I, I was given a um, like I guess a grade progress and I'm a 95 so I'm happy with that.

I: Well good.

S: Yeah.

I: And, if I were to give you a laboratory assignment to perform right now, how well do you think you would do?

S: Um, I can't say that I'd do excellent, I mean if you gave me some you know, a before warning, or like you know, explanation of what I was going to be doing, and then, kind of work or assist me as I went along, then I might do okay, but. Um, I feel like I work better when other people are around. Not, not because like you know they end up doing all the work, but I feel like brainstorming and talking things out and not feeling like I'm the only one who doesn't get stuff. That helps.

I: If you needed to take another science lab course to fulfill your core course credits, how likely would you be to take another astronomy lab course?

S: Not very likely, probably.

I: Why is that?

S: Um, well, I'm try- I'm an undecided major right now and I'm trying to figure out what exactly I want to do, so astronomy, I thought I'd never done it before, I don't know anything about it, but I've always known that I'm not really a scient- a scientific mathematic kind of person, and so taking this class has definitely opened my eyes up to a lot of things but it's kind of also let me know that I'm not going to be studying anything in the math or science area. I mean if I had to take another um, science or like lab thing then I would, the class that I would probably take, like a biology or something just because I don't know a lot about that either. But, um, I think now that astronomy out of, like, not necessarily out of the way, but that I've kind of done it, I'm, I think I'm finished.

I: How, and you, you said that um, this classes is let you know that you won't be going into the science or math area. Why is that?

S: Um, it, it's not just 'cause it's challenging for me, but I really don't, I mean, some stuff is really neat that I'm learning about like my world and my surroundings and it's neat to be able to get it, learn a lot of things that apply to you know, outside of class, when you're just like walking around at night, and you're like "oh" and you see things in the stars, in the sky, but, I think um, it deals with like concepts and and, a lot of information and a lot of facts that I don't find are like, entertaining necessarily or like crucial to a career that I might want to pursue. Or I can't really see myself having fun pursuing a job that relates to that field. I'm more of an artsy person.

I: Are you more or less confident than you were at the beginning of the semester?

S: Um, I'm more confident because I know what to expect from labs and, and um, exams, and I know that a lot of um, lecture, most of the lecture material is what, what you'll find on an exam. Um, and also the fact that I know that my TA is available to help me, you know, outside of class time, um during her office hours. And, so I know, I know what all of my options are and I know that if I'm falling behind in one area, I know that I have the option of getting help, or um, another thing is that like I know how much extra credit can help so I'm more confident about doing it and, and I know that it's something that I have to follow through with especially since this class is a challenge for me, and that. That's probably what only helped me get a 95% you know. Um, so I have to say more confident just because I'm, I'm in the know. As opposed to absolutely knowing nothing when I started.

I: And what in particular are you finding challenging about this class?

S: Um, probably just the wealth of information, just like a lot of facts and a lot of history, and I'm not really a history person either. Astronomy does involve some of that. So, um, yeah, I'd say that. And, and um, sometimes the material that we learn in class I find sort of hard to apply to like, to, to, I don't know, like a lab work or, you know, homework questions, but things that, that I'll find really fascinating like I'll really grasp and then I'll be able to apply it. But normally that's not what, that's not what I'm supposed to you know, use in the lab, so I'll just apply it to whatever everyday life, or, night sky or something.

I: And you mentioned that you've been working on extra credit for this class.

S: Mm hmm.

I: So, how would you say your effort has been in this class?

S: I'd say pretty strong, I mean, I'm given the pre-, I mean, I gue-, yeah I give this classs a good amount of time plus I do um, I do things as I get them, I try to at least. I try to do the homework as I get them, I mean since we have the syllabus and the homework is outlined for the entire semester, then you know I get a head, head start. I have my homework done like a we- mean like two weeks in advance like for this fourth homework. Just 'cause I knew that like, things kind of pile up and um, yeah, I've been to the review session for the first exam and I plan on going for the second one. I find it really helps. Um, I ask questions to my TA and not so much in cl- in lecture I feel like it's a kind of intimidating like to ask questions in front of so many people. Um, but um, yeah, I feel like I'm giving a pretty good effort into this class. Oh like, and I'm planning on like retyping, or my notes are kind of messy from lecture so I'm planning on like typing them up so I can review them, like understand what actually it says.

I: How would you rate your astronomy understand as compared to those in your laboratory section?

S: Um, I think it varies, um, there are people who I think have either, I guess, I don't know how to phrase this, like less comprehension or understanding of the astronomy concepts than I do and then there are people who are more advanced and they'll understand more, I mean partially because they're either good at math or interested in you know the science especially or they've had an astronomy course before. But I mean I guess on a scale you could say I'm like average.

I: Could you give an example of an activity in the laboratory that stressed you out, and why it stressed you out, and what you did to manage the activity?

S: Um, I can't really say that I can give you like a specific event or lab, but I mean, when things like that happen, they're usually like individual questions on the lab. Um, booklet or lab. Um, and I'll just either consult my lab partner or neighbor about that, or I'll ask, um, I'll ask (my TA), and she'll usually, I mean, yeah she always explains really well and doesn't make me feel like I'm stupid for asking or like it was, you know, it was wrong to ask. She'll be like "oh yeah, let me totally explain that to you" you know, even if it's like a hundred times, she'll do it. And so I mean, I don't really get stressed out I know that I, there are ways out of it, you know like getting help, so. I can't think of a particular experience.

I: Kind of leads into my next question. How would you describe your relationship with your TA?

S: Oh, I think it's a really good one. Um, I think that she knows that I work hard and that I'm willing to you know, do everything I can to you know, make this successful and, enjoyable class for myself. Um, at the same time, she understands that I have like, some concerns and I, would like, and the last discussion, we got this um, discussion activity and I was lost. Like I was at a mind blank you know I went up to her and I was like "I'm feeling really lost right now," and she was like "Okay." And she just explained. But she um, she knows me by my name, you know, that, you can't say that for everyone so um, and I have like, two, I have like an absence from a discussion and a lab, and you know, I was very prompt with getting her my homework that I had, and gotten her when I missed those classes, and it was because I was like in the hospital for something. And you know, she like felt really um, sympathetic towards me and. I just feel like I've been, I've been giving it my all, so she, and she recognizes that and so, you know she's um. I feel like we're close yeah. It's good.

I: And how would you describe your relationship with your classmates?

S: Um, I can't say I know a lot of my classmates, but um, those that I've worked with and my lab partner is pretty good. I mean, there aren't very many like discussion activities that we, that we get in a group or, or mingle with but um. We've done stuff in, you know lab of course, with other people, and I think that I think it's good.

I: And how did you feel about the moons of Jupiter lab?

S: The sorry, what?

I: The moons of Jupiter lab?

S: Oh. Hmm. Um, I guess kind of the same as I've felt towards every other lab. I mean I'm sure there are stuff that I can't remember specifically, but I'm sure there are some things that um, that I had trouble with and then just asked either my lab partner or teach- TA.

I: Are you finding the laboratory assignments challenging?

S: Um, yeah, some of them. I feel like sometimes I'll just glance at the um, at the lab assignment before the TA's explained anything and I'll be like "whoa," like I really don't know what, what we're doing, and she'll explain and, and then you know, she'll show us an example or I'll do it once like, even if there, if there are like you know, ten steps, and I'll get the hang of it and do it and then, that's not as challenging, and it works out.

I: Okay. Those are the only questions I have for you today.

S: Oh. Oh awesome. That was like ten minutes? Yeah.

*For transcripts of all subject data, please contact the author at brooke.carter@gmail.com. Data will be given in compliance of IRB regulations.

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