AN EXAMINATION OF GENDER DIFFERENCES IN SCIENTIFIC PROBLEM SOLVING STRATEGIES AS STUDENTS PROGRESS THROUGH AN IMPLEMENTATION OF AN ASTRONOMY MULTIMEDIA PROGRAM

by

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(Under the Direction of Martha Carr)

ABSTRACT

The present study was designed to evaluate gender differences in scientific problem solving strategies as a possible factor contributing to females’ low performance and participation in science. Two groups, a group of high interest, mostly high performing males, and a group of low interest, low performing females, were formed and studied within the context of an astronomy class implementing the NASA-sponsored Astronomy Village®: Investigating the Universe™ software program. As the students progressed through the implementation, along with their problem solving strategies, the students’ prior knowledge, performance, conceptual understanding, self-regulation, and motivation were examined to understand how these variables both impacted and were influenced by the students’ problem solving strategies. Although the males had greater prior knowledge, problem solving strategies, conceptual understanding, self-regulation, and motivation than the females, the implementation of Astronomy Village had a more positive impact on the females than the males.

INDEX WORDS: Gender differences, Problem solving strategies, Metacognition, Self-regulation, Conceptual Understanding
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CHAPTER 1
INTRODUCTION

The under representation of women in the sciences has been a concern of the United States government since the 1990’s when the National Science Foundation predicted a significant shortfall of scientists for the years to come (Enman & Lupart, 2000). Today, the problem of under representation of women in the field of science continues as women represent only 8% of employed engineers, 36% of computer scientists, and 27% of chemists (Enman & Lupart, 2000).

Gender differences in science achievement may keep women from pursuing advanced degrees and careers in science. Males receive higher grades in science classes (Felder, Felder, Mauney, Hamrin, & Dietz, 1995) and perform significantly higher on science achievement tests (Government of Alberta, 2004). Researchers have identified many possible explanations for why females perform more poorly than males in science, and why women do not continue their education or enter careers in the field of science. Some of these explanations include a lack of teacher support (She, 2001), lack of parental support (Tenenbaum & Leaper, 2003), poor motivation (Collis & Williams, 2001), lack of hands-on experience (Shin & McGee, 2002), and poor prior knowledge (Desouza & Czemiak, 2002).

Males appear to receive more social support in the classroom and at home. Males are given more attention than females in science classrooms (She, 2001). It is also known that parents believe that science is less interesting and more difficult for their daughters than for their sons (Tenenbaum & Leaper, 2003). It has been found, however, that after controlling for social
support, sex differences still exist (Foote, 1996), indicating that social support in the home and classroom does not entirely account for gender differences in performance and participation.

Much of the research on gender differences in science achievement has focused on motivation (Kaminski, 1982; Lipkin & McCormick, 1985; Manthorpe, 1982). From this research, it has been found that male middle and high school students are more likely than female students to have a positive approach to science, higher self-confidence, and higher participation rates in science, math, and technology classes (Collis & Williams, 1987). In line with this, females are more likely than males to explicitly state that they do not want a job in a scientific field (Collis & Williams, 1987). It is not clear, however, whether gender differences in motivation result in differences in science achievement or whether differences in science achievement cause females to be less interested in science.

Less research has examined potential gender differences in cognitive abilities. Some of what has been done indicates that males have more prior knowledge about science than females. For example, when examining a preschool classroom covering a unit on insects, Desouza and Czemiak (2002) found that the males had extensive background knowledge about insects and animals, and talked about their experiences catching and collecting them. This greater prior knowledge could be a result of the social support males receive in the home and classroom. Gender differences in prior knowledge are also likely influenced by students’ hands-on experience in science. Shin and McGee (2002) point out that females have fewer hands-on learning experiences than males in science classrooms. When working in groups with science materials, male students tend to be the ones who work with the lab equipment, while female students play the role of recorder and write down observations. Shin and McGee believe that this lack of hands-on experience contributes to females’ negative attitudes toward science, and that
providing females with opportunities to explore and inquire will improve both their performance and interest in science.

In addition, there is very little research to date on potential gender differences in the problem solving skills of males and females within the domain of science. What little research that has been done is inconclusive as to whether females and males differ in the ways they approach and solve problems. It is important to examine problem solving skills given these skills are necessary for correctly setting up and solving scientific problems. Given that little research has examined gender differences in science, the research on problem solving in mathematics is reviewed to provide some insight into what may be found within the domain of science. First, a description of gender differences in problem solving skills in the domain of mathematics is provided, followed by a description of the research on gender differences in scientific problem solving.

This study focused on investigating whether gender differences in strategy use translate to gender differences in achievement. First, a review of the literature on gender differences in problem solving skills in both mathematics and science is presented, followed by a review of the research pointing to the importance of efficient self-regulatory and metacognitive skills for successful problem solving. Self-regulation and metacognition are then described from a social constructivist perspective because classrooms are social environments and self-regulation is considered to be a set of skills achieved through social interaction. Finally a description of design-based research, the methodology guiding this study is provided to illustrate how problem solving and metacognition were studied.
Gender Differences in Mathematical Problem Solving

Males and females have different approaches to solving mathematics problems. When examining gender differences in mathematical strategy use in first grade students, Carr and Jessup (1997) found that males were more likely to use retrieval, whereas females were more likely to use counters or count on their fingers. Fennema, Carpenter, Jacobs, Franke, and Levi (1998) found these same gender differences in later elementary grades, with second and third grade males being more likely to use retrieval and decomposition strategies, and females more likely to use manipulatives or algorithms. When the types of strategies that the students used were controlled, males were as capable as females in calculating problems using manipulatives, but females were not as capable as males in using retrieval strategies (Carr & Davis, 2001).

These differences in strategy use may contribute to the differences in achievement and motivation that males and females experience in mathematics classrooms. Females’ tendency to use manipulatives instead of retrieval may depress their performance by slowing their transition from being novice to more expert and fluent mathematicians. Fluent retrieval is thought to allow students to become automatic at recalling facts. This automaticity allows students to devote cognitive resources to higher-level problem solving (Carr & Davis, 2001). If females are less able to use retrieval, they may not have sufficient working memory available to perform complex calculations or form a conceptual understanding of the problems. As a result, their performance, and subsequently their motivation, may decline.

Gender differences have also been found in performance on mathematical tasks. In junior high, females have been found to excel in mathematical computation (Hyde, Fennema, & Lamon, 1990; Marshall & Smith, 1987) while males excel in word problems or problems requiring mathematical reasoning (Benbow & Stanley, 1980; Fennema, 1974; Marshall, 1984).
In college, similar results were found with male students outperforming females when asked to solve word problems (Johnson, 1984). These studies indicate that females may adequately solve problems algorithmically, but are not as able to engage in advanced and flexible problem solving. When students are able to use more expert strategies such as retrieval in elementary school, they should have the short-term memory needed to focus on the conceptual understandings and reasoning skills that are stressed in later grades. Thus, the differences in the types of problems males and females are more efficient at solving when in junior high and high school may very well be an outcome of the types of strategies, retrieval or manipulatives, used in earlier grades.

The research on gender differences in mathematics indicates that gender differences in strategy use are, in part, socially driven. A study by Carr and Jessup (1997) illustrates that even though females preferred using manipulatives when working individually, when working in mixed gender groups, the males’ preferred strategy, retrieval, became the preferred strategy of both the males and females. Females seemed to voluntarily change their strategy use to match that of the males. One possible explanation is that males are more dominate in mixed group settings, while females are more submissive (Desouza & Czemiak, 2002). Therefore, when working in groups, females may play a passive role and allow the strategy of the males to dominate. If the same pattern holds true in science, males’ strategies should dominate in mixed group settings.

Parents and teachers also influence the type of strategies that students use. A study by Carr, Jessup, and Fuller (1999) examining parent and teacher influences on strategy use found that much of the instruction given on strategy use benefited males more than females. Parents and teachers reported reorienting low performing males towards the use of manipulatives and
away from the use of retrieval. These males benefited in that they had a higher correct use of manipulatives. Low performing females did not similarly benefit from parent and teacher instruction because they were already using manipulatives. Parents and teachers did not, as with males, have a logical alternative to the use of manipulatives to improve females’ mathematics achievement.

If social context affects the types of strategies that males and females use in mathematics, then social context may influence males’ and females’ strategic approaches to scientific problem solving. Therefore, along with examining gender differences in scientific problem solving strategies, it is useful to examine possible social-based influences affecting those strategies.

*Gender Differences in Scientific Problem Solving*

Only two studies have examined gender differences in the types of problem solving strategies males and females use when participating in science. When using a questionnaire to examine students’ learning strategies, Alao (1998) found no gender differences in the monitoring and elaboration strategies of fifth grade ecology students. Meece and Jones (1996) used self-reports to examine gender differences in fifth and sixth grade students’ strategies during whole class and small group science lessons. They found that average achieving females used more meaningful, and less rote strategies than average achieving males. Thus, Meece and Jones’ work does not support Ridley and Novak’s (1983) hypothesis that females use rote rather than meaningful strategies when participating in science. Both of these studies used self-reports to examine differences in the students’ strategy use. There may be problems with the validity of the reports if the students were unable or unwilling to respond accurately. Therefore it is necessary to look beyond self-reports and observe student engagement in activities and completed work in order to get a more accurate picture of these strategies.
Gender differences have also been found in performance on scientific tasks. When examining eighth grade students completing various scientific tasks, Toh (1993) found that while females outperformed males in performing the tasks, males outperformed females in communicating the results. She found no gender differences, however, in how the students interpreted the results. On the other hand, when examining high school students completing various scientific tasks, Lock (1992) found that males outperformed females in interpreting results. However, Lock found no gender differences in how the students planned out their ideas, completed the tasks, and communicated their results. When examining gender differences in the problem solving methods of high school chemistry students, Adigwe (1992) found that after controlling for students’ reasoning abilities, mathematics achievement, attitudes towards chemistry, and knowledge of chemistry, male students were more efficient in understanding and representing problems, developing problem solving plans, exhibiting the structure of their problem solving, carrying out solution plans, and evaluating solution processes. This research is inconclusive as to whether females and males differ in the ways they complete scientific tasks. Although Adigwe (1992) found that male students were more expert in solving science problems than female students, the research by Toh (1993) and Lock (1992) failed to provide conclusive results for gender differences in performance on scientific tasks.

The current study focused on examining gender differences in problem solving strategies as a possible factor contributing to females’ low performance and participation in science. The combination of poor motivation, poor prior knowledge, a lack of social support, and a lack of hands-on experience that females experience may result in females having very different approaches to scientific problem solving. Females’ lack of interest in science may contribute to their lack of hands-on learning, which may contribute to a lack of knowledge, which in turn, may
cause them to use poor problem solving strategies. In order to form a better understanding of how variables such as prior knowledge, motivation, and social support are related to students’ problem solving strategies, two groups were formed based on the research that males have greater interest than females in science classes. Interest, however, was found to strongly correspond to achievement in that the students who were more interested in science tended to have higher achievement. Therefore, a group of low interest, low performing females, and a group of high interest, mostly high performing males were formed and compared within the context of an astronomy class implementing the NASA-sponsored *Astronomy Village®: Investigating the Universe™* software program.

**Self-regulation and Metacognition**

Self-regulation and metacognition are essential for efficient problem solving and for the transition from novice to expert. Because good problem solving depends on both the appropriate selection of a strategy as well as its correct execution, efficient problem solvers can explain the strategies they are using, why they are using them, and will select another strategy if the one they are using is not working. In contrast, poor problem solvers cannot explain and monitor their choice and use of strategies, and will continue to use a strategy even after it has failed to work (National Research Council [NRC], 2001). Furthermore, high levels of metacognitive self-regulation can compensate for low problem solving ability (Swanson, 1990). What follows is a review of the literature on self-regulation and metacognition and their important role in successful problem solving.

Self-regulated learning occurs when students are “metacognitively, motivationally, and behaviorally active in their own learning” (Zimmerman, 1989, p. 4). Self-regulated learners are thought to be more effective in their learning because they have developed cognitive and
motivational strategies that they can use with proficiency to accomplish tasks, while at the same
time being capable of reflecting on and modifying their learning. Metacognition, a component of
self-regulation, has been described as “reflecting on one’s thinking” or when students “learn how
to learn,” and involves planning, monitoring, reflecting, and directing ones learning in order to
improve performance and achievement (White & Fredericksen, 1998). Traditionally, studies of
metacognition have been divided into two components: knowledge of cognition and regulation of
cognition (Howard, McGee, Shia, & Hong, 2001; Kuhn 2000; Wolters 2003). Knowledge of
cognition is a person’s understanding of his or her own cognitive abilities. Regulation of
cognition is how well a learner regulates, evaluates, and monitors his or her learning. For
example, a student who recognizes that he or she is forgetful (knowledge of cognition) may
decide to keep an organizer to help keep track of assignments (regulation of cognition).

Kuhn (2000), states that metacognition does not appear suddenly, but rather develops
early on in life and continues to progress over time as it becomes more “explicit, powerful, and
effective” (Kuhn, 2000, p. 178). Beginning at the age of three, children start to develop
knowledge of their cognition as they form an understanding of themselves as learners. For
example, children as young as the age of six come to realize that they forget information
(Bjorklund, 2000). Knowledge of cognition is thought to emerge before the regulation of
cognition, and is viewed as a prerequisite for the ability to self-regulate (Wolters, 2003). A child
who recognizes that he or she may forget information such as a phone number may decide to
write down the number. However, the child must first recognize that he or she may forget before
being able to understand that the information should be written down. Although adolescents and
adults show more metacognitive skill than children, their performance is still not perfect. Many
adults often have problems regulating their thinking and behavior (Kuhn, 2000).
Rozencwajg (2003) examined the extent to which students’ metacognitive abilities were linked to their performance in scientific problem solving on physics problems related to electricity. She found that students’ metacognitive skills were strongly related to the quality of the students’ scientific problem solving strategies. For instance, the students with higher metacognitive skills had greater conceptual understanding during problem solving, while students who had poor metacognitive skills solved the electricity problems using rote calculations. In scientific problem solving, students with high levels of metacognitive skill reflect on and monitor their strategy use. However, a student who is unable to, or fails to, reflect on and monitor his or her strategy use may use poor strategies when completing a task. Thus, it can be expected that students who have less advanced metacognitive skills will use less expert problem solving strategies.

When students monitor and reflect on their learning, they are more active in their learning, and thus form a better conceptual understanding of the information (Petros, 2000). As a result, the learning transfers, and students are able to use the material in different contexts. Ford (1998) found that students who were highly metacognitive, and monitored their learning and adjusted their behavior when they were having problems, had a greater understanding of the task, used better strategies, and as a result, had greater performance on transfer tasks. Therefore, metacognitive skills appear to assist learning, strategy use, performance, and transfer. In science this means that students with higher metacognitive skills should have better problem solving strategies and achievement, even on transfer tasks.

Although gender differences in mathematics strategy use suggest that females are less expert than males, Carr and Jessup (1997) found no gender differences in metacognitive knowledge about when, where, and how mathematics strategies should be applied. This suggests
that gender differences in strategy use may not extend to self-regulatory knowledge. In the present study gender differences in strategy use are examined, as well as how metacognitive and self-regulatory skills may influence and reflect strategy use.

Self-regulation and Metacognition from a Social Constructivist Perspective

Self-regulation has traditionally been studied as an individualistic process (Meyer & Turner, 2002). From a social constructivist perspective, self-regulation is not an individual process, but rather a set of skills achieved through social interaction (McCaslin & Hickey, 2001). In line with this, Meyer and Turner (2002) modified Zimmerman’s model of self-regulation to include the role of social interaction in the development of self-regulation. They emphasize that the classroom should be viewed as a social environment, where self-regulatory processes develop and emerge through social interaction. As an example, when students work in groups to produce a strategy to solve a problem, each student must present a rationale for his or her strategy to the other group members in order to convince them that they should use that particular strategy. When students discuss their strategies for problem solving, they are more likely to think about how, why, and when a strategy should be used, and how the strategies are tied to the underlying meaning of the problem (Carr & Biddlecomb, 1998). Through discussion, students have the opportunity to reflect on their strategies and change their strategies in response to these processes. This is assumed to decrease the likelihood that students write down answers without evaluating their responses.

Group discussions are also assumed to allow students to build a conceptual understanding that may not be attained working alone. In fact, in a science class, the teacher may find that if the students are not discussing the science concepts, then they are not learning the science (Cobern, 1993). A number of computer software programs have been designed to support the learning of
science through discussion. NASA’s *Astronomy Village: Investigating the Universe*, the software program used in this study, is an inquiry-based software program designed to be implemented in a high school classroom as a collaborative-based, and highly metacognitive learning environment.

*Design-based Research and Astronomy Village*

This study was embedded within a larger study using the methodology of design-based research. Design-based research involves forming ideas about learning, and then taking one’s ideas and materials into an everyday learning environment to observe how they are enacted in order to improve both the theory and the implementation. In trying to describe design-based research more clearly, it is useful to point out some of the differences between traditional psychological methods and those of design-based research. Unlike traditional psychological experimentation, design-based research involves working in everyday settings rather than laboratory or artificial settings, flexible design revisions rather than fixed procedures, many dependent variables rather than one or two variables, and capturing social interaction rather than isolated learning (Barab & Squire, 2004). When performing design-based research, one implements their theory and materials in a real classroom environment. This environment is spontaneous and messy. For this reason, immediate and flexible revisions may need to occur in order to assist and improve the learning environment. Because design-based research views educational interventions as holistic (Design-Based Research Collective, 2003), there are many dependent variables that play a role in the results. For instance, in an implementation, the interactions between the materials, activities, teacher, and students all influence learning outcomes. Finally, since the implementation involves multiple variables that work together in an actual classroom, design-based research captures social interactions.
Although a central aspect of design-based research is the concern for the extent to which useful new ideas are tied to various contextual factors, searching for and understanding these factors are essential if others are to apply and extend that knowledge to new domains and contexts. Therefore, with design-based research, any lessons learned not only apply to the context in which one is working, but are anticipated to generalize to different learning environments. The immediate refinements incorporated into the learning environment help the students within the context studied, while plans for future refinements contribute to future educational implementations as insights that can help change curriculum, materials, and teaching methods (Clarke, 2003).

Consistent with design-based research, the implementation was examined for ways to refine the materials and classroom learning environment to make them more useful not only for the two focus groups, but for all students in both this and similar contexts.
CHAPTER 2

METHOD

Participants

Participants included 15 eleventh and twelfth grade astronomy students from a middle class high school in Georgia. The nine males and six females participated with the permission of parents and teacher.

Students used the Astronomy Village software for four weeks, over 20 class periods. Students were assigned to groups of three, forming a total of five groups. The first two groups were formed on the basis of gender, as well as interest as assessed by the teacher. One group was comprised of three low interest females and one group was comprised of three high interest males. Although the groups were formed based on interest, the students’ interest strongly corresponded to their previous semester astronomy grade. Of the six females in the class, the three low interest females had received the lowest grades. Of the nine males in the class, two of the high interest males received the highest grades, while the third male fell among one of the lowest grades of the nine males. For the females, performance and interest were closely related, but this was not necessarily the case for the males.

The other three groups were formed based on the students’ ability to work well with one another. These groups included one group of three males, one group of two females and a male, and one group of two males and a female. During the second week of the implementation, a new female student joined the class and assembled into the group of two males and a female. Subsequently, one of the males of the group joined the all male group. Of the five groups, the
low interest, low performing females, and high interest, mostly high performing males were studied during the implementation and their prior knowledge, performance, problem solving strategies, conceptual understanding, self-regulation, and motivation were closely examined.

Procedure and Materials

Curriculum and Assessment Design and Administration

The project started by identifying 13 of Georgia’s Quality Core Curriculum (QCC) standards that were well-matched to the various investigations in the Astronomy Village software. A four-week curriculum was then developed, targeting the 13 standards. This resulted in four of the ten Astronomy Village investigations being included in the curriculum. In addition, within each investigation, the 11 to 23 possible activities were examined and a subset was identified as most relevant based on their application to the investigation topic, ability to be completed in four fifty-minute class periods, and their alignment to the standards. Finally, for each of the 13 state standards, corresponding national standards and standards from the local system were also selected.

Three “levels” of assessment were developed for this curriculum, and were administered to students throughout the four-week implementation. These assessments included four activity-oriented quizzes, a curriculum-oriented exam, and a standards-oriented test. Four days before the implementation of Astronomy Village, the standards-oriented test was administered to the students as a pretest. In addition to the pretest, the curriculum-oriented exam was administered as a subcomponent of the pretest. During the implementation, on the fifth day of each week (after students spent four days working on activities), an activity-oriented quiz was administered to the students. Upon the completion of the each quiz, students participated in feedback conversations over the quizzes using detailed answer explanation sheets and review routine steps. Upon the
completion of the implementation, two days following the last quiz, the curriculum-oriented exam was administered for a second time as a post-exam. Students spent the day after the post-exam engaged in feedback conversations over the exam. Exactly two days following the post-exam, the standards-oriented test was administered for a second time as a posttest.

**Standards-oriented Test.** Four days prior to the implementation of *Astronomy Village*, a 20-minute test was administered to students. The test was “standards-oriented” because it was formed with a focus on the targeted science standards rather than the curriculum. In developing the test, a pool of multiple choice questions was created by aligning astronomy questions from various public domains to the 13 QCC standards that were to be covered during the four-week implementation. Specifically, 2 to 40 multiple choice questions were aligned to each QCC standard, forming a pool of 102 questions. From this pool, two questions for each of the 13 QCC standards were randomly selected to form a 26 question test. In addition to the 26 questions (four of which were inquiry based), the test also included an “inquiry triangle” which included three inquiry items that were domain general, and not tied to any particular subject area. The seven total inquiry items were included in the test in order to examine the influence of *Astronomy Village*’s inquiry-based learning environment in improving students’ ability to solve astronomy, as well as general inquiry type problems. In all, the test included a total of 29 questions (see Appendix A for a copy of the test). The test was assembled in a manner that would allow for valid comparisons across any curriculum that targeted the specified standards, permitting valid estimations of the impact on the assessed students’ performance on any high-stakes test items assessing those same standards.

**Curriculum-oriented Exam.** A curriculum-oriented exam was administered as a subcomponent of the test (see Appendix B for a copy of the pre-exam). The exam was
“curriculum” oriented because it was designed to assess the broader content that was targeted by the activities. The exam consisted of 13 multiple choice questions, one question aligned to each of the 13 QCC standards that were to be covered during the four-week implementation. The questions for the exam were selected from various public domains, and were selected with a focus on the concepts and skills that would be covered in each of the four investigations of *Astronomy Village*.

*Implementation of Astronomy Village.* For each of the four weeks, students worked in their groups and participated in an investigation of a single topic, including in the order in which they were completed, *Stellar Nurseries, Search for Nearby Stars, Variable Stars*, and *Search for a Supernova*. Students followed a path diagram for each investigation (Figure 1). The purpose of the path diagram was to help organize and break-up the activities into components of background research, data collection, data analysis, and data interpretation (the presentation section of the path diagram was replaced with activity-oriented quizzes). The path diagram encouraged coherence and prevented cognitive overload by organizing the activities. Furthermore, the five phases of the path diagram, as well the activities within the path diagram supported inquiry-based learning. Inquiry-based learning, which involves being an active learner, differs from many traditional science classroom curricula that focus on memorizing facts, definitions, and formulas (White & Fredrickson, 1998). It was found that in *Astronomy Village: Investigating the Solar System*, a similar software package to *Astronomy Village: Investigating the Universe*, that students who used the software improved in both their understanding of specific astronomy concepts and their ability to engage in inquiry (McGee, Howard, Dimitrov, Hong, & Shia, 2001).

While students could spend weeks on a single investigation, the students in this implementation had four days to work on each investigation. For each investigation, a path
diagram contained approximately 11 to 23 possible activities. Although all the activities focused on helping students form an understanding of the overall main idea of the investigation, certain activities were considered more relevant and essential because they pointed to the key inquiries and core concepts of the investigations while at the same time covering the related QCC standards. As a result, of the many activities contained in a path diagram, specific activities were suggested to students as most useful for a deep understanding of the investigation. However, these suggested activities were optional for completion, and were not required. As a result, students ultimately chose which activities to engage. Students could participate in only the suggested activities, complete more than what was suggested, less than what was suggested, or even form their own curriculum. Curricular outlines with suggested activities for each of the four investigations can be seen in Appendix C. It was expected that allowing students this autonomy in selecting activities and managing their time would afford them with opportunities to self-regulate their learning as they worked to focus on relevant and important material.

At the beginning of each investigation, a statement of problem was meant to be issued to each group of students. The statement of problem included a simple introductory question accompanied by an overview of what students would be studying in the investigation. The statement of problem was meant to help frame the design of the investigation, help students understand how the activities contribute to the main idea of the investigation, and introduce students to what they were about to learn (See Appendix D for the *Search for Nearby Stars* statement of problem). However, the teacher only issued the statement of problem during the first week.

Each group was also issued an investigation logbook at the beginning of each investigation. For the different types of activities, students were asked to either record main
ideas, record observations, answer questions, or formulate questions. Thus the logbooks provided students with the opportunity to reflect on what they had learned. The fact that the logbooks included every activity in an investigation encouraged students to self-regulate, as it required them to make decisions about which activities to take part in, which activities to summarize, and how to summarize their knowledge (See Appendix E for the *Search for Nearby Stars* Investigation Logbook). Each of the investigation logbooks were collected from all of the groups at the end of each week, and the logbooks of the low interest, low performing females, and the high interest, mostly high performing males were studied for problem solving strategies, conceptual understanding, and self-regulation.

*Activity-oriented Quizzes.* After spending four days working on *Astronomy Village* activities, on the fifth day of each week, students were administered an activity-oriented quiz. The quizzes were “activity-oriented” because they were closely aligned to the specific activities that students had just completed. Each quiz, which aimed towards covering the QCC standards studied that week, represented most of the week’s suggested activities, and focused on assessing the main idea or theme of the investigation. Each quiz usually consisted of one or two questions divided into parts A and B, with part A requiring only a short answer, and part B requiring a further explanation of part A (See Appendix F for activity-oriented quizzes for weeks 1-4). Because each investigation and the activities within the investigation focused on a major astronomy topic such as how to find distances to nearby stars or the understanding of variable stars, quiz questions were not specific to a single article, lecture, or activity, but were questions about the topic in general. As a result, the one to two questions on each quiz were able to focus on the overall main idea of the investigation and represent most of the week’s activities. Finally, the quizzes focused only on important concepts and content targeted in the *Astronomy Village*
curriculum and used similar if not identical wordings and images (e.g., graphics and diagrams) as the software, thus creating a “near transfer” of knowledge from the curriculum.

After students individually completed their quizzes, they assembled into their assigned groups to engage in “feedback conversations” over their quizzes using review routine steps and “answer explanations.” Students were first given the review routine steps (Appendix G) which provided the students with instructions on how to engage in the feedback conversations. For each item on the quiz, students were expected to first share and explain their initial answers with their group members. Then the groups were to come to a preliminary consensus on the most sensible solution for each question. Finally, students were administered the answer explanations (see Appendix H for quiz answer explanations for weeks 1-4) and were told to read them, and use them to come to an understanding and final consensus for each question. The answer explanations described in detail the rationale for each question on the quiz and tried to avoid directly stating answers. Furthermore, the answer explanations often included analogies to help students connect what they knew to what they were learning. Glynn and Takahashi (1998) found that adding analogies to science text enhanced learning and retention of the concepts, particularly for novice students who lacked content knowledge. Thus the analogies were expected to help students understand some of the more difficult concepts. Overall, the feedback conversations were divided into two parts, with students first discussing their initial responses on their quizzes to come to a preliminary consensus on a most sensible solution, and second, reading and reviewing the answer explanations to come to a final consensus on a most sensible solution.

There were no time restrictions on either the quiz or the feedback conversations, and students were encouraged to take their time. For the first and second quiz, students spent approximately three minutes individually completing their quizzes, and five minutes within their
groups, discussing their answers and coming to an initial consensus for each question. The teacher then provided students with the answer explanations in which students spent approximately three minutes reading and reviewing the answer explanations and coming to a final consensus for each question. Finally, the teacher spent about five minutes reviewing the quiz with the entire class.

For the third quiz, students spent three minutes individually completing their quizzes, and fifteen minutes within their groups discussing their answers with their group members to come to an initial consensus for each question. During this time, the teacher, who was encouraged to facilitate the group discussions by asking students questions about their responses (without inserting content into the conversations) in order to encourage the students to further reflect on and discuss their ideas, moved from group to group, engaging the groups with questions about the quiz. Students then received the answer explanations and spent three minutes reading and reviewing the answer explanations in order to come to a final understanding and consensus for each question. The teacher then reviewed the concepts on the quiz with the entire class for approximately nine minutes.

For the fourth quiz, students spent nine minutes individually completing their quizzes. Students then spent nine minutes discussing their answers with their group members trying to come to an initial agreement on the questions, while the teacher moved around the classroom, asking the students about their responses to the quiz questions. The students were then issued the answer explanations and spent five minutes reading and discussing the answer explanations in order to come to a final consensus for each question, until the teacher concluded the feedback conversations for a five minute discussion over the quiz.
Although the quizzes were not collected for a grade, a weekly participation grade was given by the teacher to help keep the students on task. The participation grade was based on how much the students appeared to stay focused and involved in the feedback conversations. The group of low interest, low performing females, and group of high interest, mostly high performing males were videotaped as they engaged in feedback conversations over all four of their quizzes, and their discussions were studied for problem solving strategies, teacher influence on those strategies, conceptual understanding, self-regulation, and motivation. After the completion of each quiz and feedback conversation, all the students in the classroom were issued a questionnaire (Appendix I) with questions designed to assess which activities and interventions were most effective in engaging the students’ interest and learning. This was useful for determining how to improve the curriculum to make it more useful and appealing for students. Although the questionnaire was also designed to assess changes in the students’ motivation, self-regulation, and conceptual understanding, these questions failed to elicit useable responses.

Post-exam. At the end of the implementation, the day following the final activity-oriented quiz, the curriculum-oriented exam was administered for a second time. This post-exam was the same as the pre-exam with the exception of two questions. Due to a ceiling effect on two of the items on the pre-exam, the two items were dropped and two additional questions aligned to the same QCC standards as the two that were eliminated were added to the post-exam (see Appendix J for a copy of the post-exam). These two additional questions were analyzed separately from the 11 questions that were identical on the pre and post exam.

Unlike the pre-exam, the post-exam was collected and graded by the teacher as part of the students’ grade in the class. Furthermore, students spent the day following the administration of the post-exam reviewing and discussing their graded exams using the review routine steps and
exam answer explanations similar to the answer explanations administered after the activity-oriented quizzes (see Appendix K for the post-exam answer explanations). Students spent approximately eight minutes discussing their answers within their groups to reach an initial consensus for each question, and three minutes reading and reviewing the answer explanations to come to a final agreed understanding on the quiz questions until the teacher concluded the feedback conversations with a six minute discussion over the exam.

Although the questions on the post-exam focused on concepts and skills that students had studied during the four-week implementation, because the exam questions were selected from public domains, the post-exam tested the knowledge of the curriculum on a broader level than that of the activity-oriented quizzes. Therefore, the post-exam created a “medium transfer” of knowledge from the *Astronomy Village* curriculum, and the pre and post exam functioned as a pre-post measure of medium-transfer learning gains.

*Posttest.* The day following the feedback conversations over the post-exam, the standards-oriented test was administered for a second time. The posttest was the same 29 question pretest. Although the pre-post test questions were aligned with the QCC standards covered during the four weeks, the pool of items that the questions on the test were randomly selected from was formed with a focus on the standards rather than the curriculum. For this reason, the items on the test assessed content not necessarily taught in the *Astronomy Village* curriculum. Therefore, the posttest created a “far transfer” of knowledge from the *Astronomy Village* curriculum, and the pre-post test functioned as a pre-post measure of far-transfer learning gains.
Assessment Rationale

The formation and administration of these assessments were based on an assessment model designed by Hickey (2003). The assessments represented a comprehensive framework designed to help align innovative curriculum with external tests by balancing formative and summative functions within and across levels. For instance, while the quizzes and exam allowed for discussion and student feedback in a way to immediately and directly benefit the students, the test emphasized and reflected the summative function of high-stakes assessments by focusing on state standards. Thus, the three levels of assessment allowed the opportunity to bridge the gap between the “immediacies” of a technology-based learning environment and the “abstraction” of standards (Zuiker & Hickey, 2004).

In addition to studying differences in the problem solving strategies, conceptual understanding, self-regulatory skills, and motivation of the low interest, low performing females, and high interest, mostly high performing males, pre and post exam and test scores were analyzed for performance gains for all the students in the classroom, while classroom observations, interviews with the teacher, and self-reports from the students were studied for ways contextual factors, such as the curriculum and teacher facilitation, influenced the high interest males’ and low interest females’ problem solving strategies.
Figure 1: The Astronomy Village interface and the path diagram for the *Search for Nearby Stars* investigation.
CHAPTER 3
RESULTS

Females typically score significantly lower than males on science achievement tests (Government of Alberta, 2004) and receive lower grades than males in science classes (Felder, Felder, Mauney, Hamrin, & Dietz, 1995). This study was designed to assess how males and females approach scientific problem solving within the context of an astronomy classroom in order to understand a possible factor contributing to gender differences in achievement. To determine the impact of problem solving strategies on science achievement, two groups, a group of low interest, low achieving females, and a group of high interest, mostly high achieving males, were assessed as they progressed through the four-week implementation of the Astronomy Village software program.

Of particular interest was the impact of the implementation on the performance, problem solving strategies, conceptual understanding, self-regulation, and motivation of the two groups as they progress through the implementation. It was found that the implementation of the Astronomy Village program more positively affected the females than the males. The females began the program with low prior knowledge, but made higher achievement gains than the male group and whole classroom. In addition, their problem solving strategies and self-regulation improved over the four-week period. However, the females’ low conceptual understanding and low motivation did not appear to improve. The males who had high prior knowledge at the outset also showed achievement gains, but these gains were not as significant as those of the females or the class as a whole. Although the males started the program with good problem solving
strategies, good conceptual understanding, and excellent self-regulatory skills, their self-regulatory skills improved over the four-week period, while their conceptual understanding remained relatively stable. The quality of their problem solving strategies decreased over the four-week period. Finally, the males’ already high motivation remained stable throughout the implementation.

For each group, pre-post exam and test scores were examined for improvements in performance. Prior knowledge was assessed by examining pre-exam and pretest scores. Logbooks were examined for problem solving strategies, conceptual understanding, and self-regulation. Videotapes of the students engaging the feedback conversations over the quizzes were examined for problem solving strategies, teacher influence on problem solving strategies, conceptual understanding, self-regulation, and motivation. Although the tapes were coded more specifically for metacognition rather than self-regulation, because metacognition is a component of self-regulation (Zimmerman, 1989), the term self-regulation was used to maintain clarity. Changes in motivation were also assessed through classroom observations. Appendix L provides an outline of the specific logbook activities and feedback conversations that were analyzed for problem solving strategies, conceptual understanding, and self-regulation. The videotapes and logbooks were analyzed by two coders who compared their analysis to resolve differences in interpretation. There was a 99% interrater agreement. The findings for the females are first described followed by the results of the group of males. Then a description of the implementation within the overall classroom helps provide a more in-depth and comprehensive explanation of how the implementation played out, and the context in which these two focus groups worked. Finally, recommendations for how to help improve the implementation to
increase the performance of all the students in the classroom are provided. The specifics of the analyses of the data are presented below.

*The Impact of the Curriculum and Assessment Materials on the Low Interest, Low Performing Females*

Changes in the females’ performance, strategy use, conceptual understanding, self-regulation, and motivation as a function of the *Astronomy Village* curriculum are reported below. In general, the females’ performance improved, as did their strategy use and self-regulatory skills. No changes in conceptual understanding and motivation, however, were found for this group.

*Changes in Performance*

Two of the three females took both the pre and post exam. The females improved their exam scores from the pre-exam to post-exam. There were 11 items that were the same from the pre to post exam. Female 1 received a 3.0 out of 11 on the pre-exam and an 8.0 out of 11 on the post-exam, improving her score by five points. Female 2 received a 9.0 out of 11 on the pre-exam and a 10.0 out of 11 on the post-exam, improving her score by one point. The females’ average pre-exam score was 6.0 out of 11 items correct, while their average post-exam score was 9.0 out of 11 items correct (see Table 1). Therefore, of the 11 items, the two females’ exam score increased by an average of 3.0 points.

The females also made slight gains in scores from the pre to post test. There were 29 items on the pre and post test. Female 1 showed no improvement on the test. She received a 12.0 out of 29 on the pretest and a 12.0 out of 29 on the posttest. Female 2 received a 14.0 out of 29 on the pretest and a 16.0 out of 29 on the posttest, increasing her score by two points. Female 3 received an 18.0 out of 29 on the pretest and a 19.0 out of 29 on the posttest, improving her score by one point. The females’ average pretest score was 14.67 out of 29 items correct, while their
average posttest score was 15.67 out of 29 items correct (see Table 1). Therefore, of the 29 items, the females’ test score increased by an average of 1.0 point.

The females’ low scores on the pre-exam and pretest illustrated how they began the implementation with low prior knowledge about astronomy. Compared to the gains of the entire class and to those of the high interest males, on the exam, the females improved their score by an average of three points, which was 1.34 points higher than the average gain of the males (males’ average pre-exam score: 8.67; males’ average post-exam score: 10.33; average gain: 1.66), and .75 points higher than the average gain of the entire class (class’s average pre-exam score: 7.17; class’s average post-exam score: 9.42; average gain: 2.25). On the test, the females’ gains were equal to those of the males (males’ average pretest score: 17.67; males’ average posttest score: 18.67; average gain: 1.0). The female group also gained an average of .15 points higher than that of the entire class (class’s average pretest score: 15.29; class’s average posttest score: 16.14; average gain: .85). Therefore, the females’ low prior knowledge allowed for them to benefit from the curriculum in a way that their gains on the exam were greater than that of the males and class as a whole, and their gains on the test were equal to the males and higher than that of the class as a whole.

**Problem Solving Strategies**

Logbooks were collected from the females to assess their problem solving strategies. Problem solving was also assessed via the videotapes of the females participating in feedback conversations over their quizzes. The females’ problem solving strategies as assessed by the logbooks are first described followed by a description of the females’ problem solving strategies while participating in the quiz feedback conversations.
Examination of Logbooks for Problem Solving Strategies. The logbook for the fourth week was not collected from the teacher, and as a result, the logbooks from only the first three weeks were used to examine the females’ problem solving strategies. For each week, problem solving strategies were analyzed and categorized as topic sentence, guessing, and summarization strategies. Specifically the topic sentence strategy involved incorrectly selecting a specific sentence almost verbatim from the text and including it as a main idea. Although this strategy could be used correctly 11 out of 24 possible times, it was an ineffective strategy 13 times when there was no topic sentence. Therefore, besides the 11 exceptions when there was a topic sentence in the passage, the strategy was a poor choice because it resulted in the selection of a sentence from the text that was either tangentially or not at all related to the main idea of the text. When the topic sentence strategy was used correctly, it was unclear whether its use was indicative of a real understanding of the topic or whether it was selected because it stood out in the text. For this reason, when the topic sentence strategy was used correctly, it was reported separately as topic sentence used correctly. The guessing strategy involved providing a response based on estimates and guesses. Unlike the topic sentence strategy, it did not involve copying a sentence verbatim from the passage. The summarization strategy involved correctly summarizing the text to provide accurate responses to the questions. These strategies were coded for each of the suggested activities (suggested activities included a subset of activities in an investigation suggested to students as most useful for completion) in the logbook for which students were asked to describe the main idea of the activity. Changes in strategy use were examined across the three weeks that the logbooks were collected.

Based on the logbooks, across the three weeks, the females improved in their problem solving strategy use. During the first week, students completed the investigation Stellar.
Nurseries. For this week, three of the seven suggested activities, the lecture “Star-Forming Regions,” the article “Introduction to the Electromagnetic Spectrum,” and the article “Multiwavelength Astronomy” required students to describe the main idea of the activities. The females completed two of the three activities: the lecture and the “Introduction to the Electromagnetic Spectrum” article. The females were required to write three sentences describing the main idea of both the lecture and article, for a total of six sentences. Below is an example of the female group’s response to the “Star-Forming Regions” lecture:

**Write 3 sentences about the main idea of this lecture:**

The lecture is about why astronomers observe at different wavelengths of light. It talks about how stars form and how it is a mystery. Stars in our galaxy are made of dust and gas.

For the first sentence, the topic sentence strategy was used correctly. Both the second and the third sentence were scored as incorrect use of the topic sentence strategy because they were statements taken almost verbatim from the text and were used to incorrectly summarize the main idea of the lecture. Star formation being a mystery is irrelevant and the last sentence is comprised of trivial facts, unrelated to the main idea of the lecture.

Overall, out of a total of six possible sentences, the females used the topic sentence strategy incorrectly three times, twice in the lecture, and once in the article. The topic sentence strategy, which could be used correctly three times during this week, was used once during the lecture and once during the article activity. Finally, the guessing strategy was used once during the article activity.

During the second week, students completed the investigation *Search for Nearby Stars.* In the logbook, four of the nine suggested activities required students to write three sentences to
summarize the main idea of the activity, for a total of 12 sentences to be written. These activities included, in the order students completed them, the lecture “Searching for Nearby Stars,” the article “Brightness of Stars,” the article “Distances to Nearby Stars,” and the article “A Grand Tour of the Universe.” The females incorrectly used the topic sentence strategy once in the first activity and twice in the second activity. They also used the guessing strategy once in the first activity and once in the third activity. In these first three activities, for the four times the females were not using the guessing strategy or the topic sentence strategy incorrectly, they used the summarization strategy. In the last activity, the females used the topic sentence strategy correctly twice, and the summarization strategy once. Overall, the summarization strategy was observed five times during this second week.

In the Variable Stars investigation logbook for the third week, three of the seven suggested activities required students to write three sentences to summarize the main ideas. These activities included the article “Variable Stars,” the article “Candles to Light the Night,” and the lecture “Variable Stars.” The females only completed two of the three activities, the lecture and the “Candles to Light the Night” article. The topic sentence strategy was used twice, once correctly during the lecture, and once incorrectly during the article. For the other four statements, the summarization strategy was used.

Table 2 illustrates a summary of the females’ use of the different strategies when completing the logbooks. Because the females worked in groups to complete the logbooks, the strategy of the group is always reported. The table shows that the females improved in their strategy use as they used the summarization strategy more often and the topic sentence strategy and guessing strategy less often. The females’ use of the summarization strategy increased from 0% during the first week to 42% during the second week to 67% during the third week. The
females’ use of the topic sentence strategy (used incorrectly) decreased from 50% during the first week to 25% during the second week to 17% during the third week. The females’ use of the guessing strategy also decreased from 17% during the first and second week to 0% during the third week. The number of times the topic sentence strategy was used correctly is also reported, and was used five of the 11 total possible times it could be used correctly.

**Examination of the Quiz Feedback Conversations for Problem Solving Strategies.**

Videotapes of the females as they participated in the quiz feedback conversations were also coded for problem solving strategies including the topic sentence strategy, the summarization strategy, and the guessing strategy. More specifically, these strategies were coded as the students participated in the segment of the feedback conversation where they received the answer explanations. The females were observed to see how they used the answer explanations to come to a final consensus on the quiz questions. Because the females worked in groups during the feedback conversations, the strategy of the group is always reported. Although improvement in strategy use was evident in the logbooks as the females began to use the summarization strategy more often, and the guessing and topic sentence strategies less often, this same improvement was not evident in the feedback conversations over the quizzes. Rather than using the answer explanations to help them further understand the concepts, the females looked at the answer explanation sheet for explicitly written answers. Although the females used the topic sentence strategy for all three of the times the strategy could be used effectively, because the answer explanations were written in a way that almost all of the answers were implicitly rather than explicitly written, the topic sentence strategy was usually ineffective. As a result, the females would often use estimates or guesses to develop an answer. This guessing strategy led to the correct answer only one of the six times it was used.
During the first quiz, for the three questions, the females used the guessing strategy twice and the topic sentence strategy correctly once. During the second quiz, for the four questions, the females used the guessing strategy twice and the summarization strategy twice. During the third quiz, for the two questions, the females used the topic sentence strategy correctly twice. For the fourth quiz, for the three items, the females used the guessing strategy twice, and the summarization strategy once. For the 12 total questions, the females used the topic sentence strategy correctly three times, the topic sentence strategy incorrectly zero times, the guessing strategy six times, and the summarization strategy three times.

As illustrated in Table 3, the females’ strategy use while engaging in the feedback conversations varied, but did not improve. For instance, the females’ use of the summarization strategy increased from 0% during the first week to 50% during the second week, and then dropped back to 0% during the third week, and rose back up to 33% during the fourth week. The females’ use of the guessing strategy decreased from 67% during the first week to 50% during the second week to 0% during the third week, but rose back up to 67% during the fourth week. Although the females’ use of the guessing strategy decreased from the first to the third week, besides the third week, their use of the guessing strategy remained high throughout the four weeks. Furthermore, besides the second week, the females’ use of the summarization strategy was low during the four weeks. The number of times the topic sentences strategy was used correctly is also reported and was used for all three times it could be used correctly.

**Conceptual Understanding**

The females’ use of the topic sentence and guessing strategy appeared to inhibit their conceptual understanding. Conceptual understanding was assessed in two ways. First, it was assessed based on the females’ logbook responses to the thought questions. These thought questions were
different questions from those asking students to write three sentences describing the main idea of the activity. Instead, the thought questions required students to think hypothetically about the concepts they were learning. Second, conceptual understanding was assessed based on the students’ collective final consensus responses to the questions on the quizzes asking students to explain their understanding of the concepts. These responses were observed as the females engaged in the quiz feedback conversations. Because the students completed the logbooks as a group, and when engaging in the feedback conversations, the students were instructed to review the answer explanations to come to a final group consensus, it was the conceptual understanding of the group that was of interest.

*Examination of Logbook Thought Questions for Conceptual Understanding.* When completing the thought questions in the logbooks, the females failed to provide responses that suggested a conceptual understanding of the material they were learning. For instance, in the second week investigation logbook, a thought question asked students to imagine a situation in space. Below is an example of a response that would require a good conceptual understanding of the concepts.

*Imagine this:* You are an astronomer on Earth observing one star eclipsing another. If you could observe the same stars from a planet located directly above the stars, what would you see?

*Response:* You would see one star rotating around the other. This is what a binary star system would look like.

For the two out of three thought questions that the females completed, neither of their responses was answered in a way that indicated that they had formed a conceptual understanding of the
material. Instead, the females’ answers were comprised of sentences that made no sense and were a result of guessing.

*Examination of the Quiz Feedback Conversations for Conceptual Understanding.*

Conceptual understanding was assessed based on the students’ collective final consensus responses to the questions on the quizzes asking students to explain their understanding of the concepts. More specifically each quiz usually consisted of one or two questions divided into parts A and B, with part A requiring only a short answer, and part B requiring a further explanation of part A. It was the responses to part B (except for item 1b on the first quiz) that were scored for conceptual understanding. Only two out of four times, once during the second week and once during the third week, were the females able to come to a correct final response to part B of the questions requiring students to explain their responses.

It may be that the females’ primary use of the guessing strategy when engaging in the feedback conversations, and frequent use of the guessing and topic sentence strategies when completing the logbooks inhibited their conceptual understanding. The females were never able to provide correct responses to the logbook thought questions requiring them to think hypothetically about the concepts they had learned. In order to do so, they would have needed to develop a deeper conceptual understanding of the concepts that could have been gained through the use of the summarization strategy during the logbook activities asking for main ideas. Furthermore, the primary use of the guessing strategy when using the answer explanations during the feedback conversations most likely prevented the females from being able to come to a final correct answer more than twice.
Changes in Self-regulation

Self-regulation was assessed in two ways. First, self-regulation was assessed by examining the logbooks and calculating the number of activities the females completed in the logbook each week to see if the females were increasingly self-regulating their learning by completing more activities. Second, the videotapes of the females engaging in the feedback conversations were examined for self-regulation. The videos were examined to see if the females were increasingly reflecting on, monitoring, or questioning their thinking, and how their statements influenced and reflected their strategy use.

Examination of Logbooks for Self-regulation. Self-regulation was calculated by summing the number of activities students completed in the logbooks each week. The female group appeared to improve in their self-regulation over the four-week period. During the first week, the females failed to complete three of the seven suggested activities. During the second week, the females completed all of the entries in the logbook for the nine suggested activities. During the third week, the females only failed to complete one of the seven suggested activities. Therefore, by the third week, the females were completing more activities than the first week. The females appeared to be paying more attention to what needed to be done and were making sure that the work was done. Furthermore, the additional knowledge gained with the passing of each week may have helped them work more quickly and efficiently. The fact that females completed more activities during the second and third weeks may have assisted their conceptual understanding on the quizzes during these two weeks.

Examination of Videotapes of the Feedback Conversations for Self-regulation. The videotapes of the females participating in the feedback conversations during the four-week
period were examined for self-regulation. Evidence of self-regulation included behaviors and verbalizations in which the females were reflecting on, monitoring, or questioning their thinking.

For week one, five metacognitive statements were recorded. All of the occurrences, which included utterances such as “I’m not sure” or “I have no idea,” involved the females recognizing their lack of knowledge about the concepts on the quizzes. During the second week, eight metacognitive statements were recorded. During this week, the females had fewer “I don’t know” statements and began to make more statements such as “[I wonder] why is this like this?” that indicated that they were monitoring their learning. During the third week, eleven metacognitive statements were recorded. An important observation made during this week was that the females recognized that they were confused about the concepts, but were also frustrated at not being given the answer explanations so that they could determine the correct answers. They mentioned “so we don’t know now and we won’t know it until we get the paper [answer explanation].” However, their reflections also included statements like “I think there is something more to it.” Thus in addition to an increase in the quantity of the females’ metacognitive comments, there appeared to be a difference in the quality of the statements as females were monitoring and questioning their thinking more elaborately during this third week.

During the fourth week, nine statements of metacognition were recorded. The number of metacognitive statements most likely decreased during this week because the quiz was not very complex. Many of the females’ statements consisted of “We both think so,” “I agree with her,” and “Where does it say the answer [on the answer explanations]?” This again indicated that the females were not questioning their learning, but rather were focused on obtaining an answer.

It was initially assumed that the discussion around the quizzes would help increase and improve metacognitive reflection, which in turn would help students reflect on and improve their
strategy use. Although the females did reflect on, monitor, and question their thinking more, their metacognitive statements did not encourage them to use better strategies during the feedback conversations. However, it may have helped with their improved strategy use when working on the logbooks. The females’ statements reflected their use of the topic sentence and guessing strategies, especially when engaging in the feedback conversations, as the females either focused on finding an explicitly written answer, or focused on agreeing on a guessed answer.

**Teacher Impact on Student Problem Solving**

The videotapes were also examined to assess the teacher’s role in facilitating the feedback conversations during the third and fourth weeks. Of particular interest was the impact of the teacher on the females’ problem solving strategies. Although the teacher did scaffold the females during the third and fourth quizzes with questions about their responses to the quizzes, he did so in a way that discouraged them from discussing and reflecting on the concepts. For instance, during the third week, to help the females better understand Cepheid variable stars, the teacher approached the females with an analogy of a lamp that could be switched to various brightnesses. Below is the female group’s interaction with the teacher discussing the quiz question on Cepheid variable stars.

T: Did you figure out number 2 you think?

A: We all got the same thing; we’re not sure if it’s right.

T: And the same thing is what?

A: They’re kind of just like a marker for a certain distance.

E: (starts to talk but is quickly cut off by teacher)

T: I was talking to them, and do any of you have the lights at home that can get two different brightnesses? You know you click it once and it’s dim; you click it twice and it’s kind of
A: Well it’s that thing you turn (illustrates with hand)

T: Yeah, or like a dimmer switch too, some people have dimmer switches in your dining room. That’s kind of what these stars are doing and you can in some ways you can maybe get distances out of that because when it’s on dim I have to get pretty close to read my book, right. But when I put it on bright, now I can sort of be farther away to read a book. So in a way sort of the brightness of the source kind of helps you figure out distances is what they’re getting at.

A: Mm-hmm.

T: Now the question that I asked before is do you think the star’s farther away from us six days later? See this is kind of a six day cycle (pointing to quiz). Do you think it’s gotten very much father or closer to us?

K: Uh-huh

E: No.

T: No, it’s probably more the star’s changing its intensity than it is the distance. Cause that’s not gonna change very much in 6 days, and that might change in, you know, 10 million years.

The teacher’s questions were direct, and the females responded with simple yes or no answers. He then fed them known-answer questions to which they responded with the appropriate answer (given his implicit direction). This facilitation was centered on the teacher getting the ideas or basic facts across rather than encouraging the females to discuss their ideas to form the right understandings. This sort of teacher facilitation may have contributed to and helped maintain the females’ use of topic sentence and guessing strategies by encouraging them to provide a right answer or a product, rather than encouraging them to discuss and reflect on their ideas.
Observations of Motivation

Low interest, poor performing females differed from their higher performing male counterparts in that they showed little interest in the topic at the beginning of the program. This lack of interest, which was assessed through classroom observations of the females engaged in activities and the timing of the females’ engagement in the feedback conversations, continued throughout the intervention. This suggests that the implementation did not improve the interest of these low performing females.

When completing the activities, the females appeared less interested than the group of males and any of the other groups of students in the classroom. For instance, during the first day of the implementation, students were given a lab and an article to complete. The teacher gave the students the article to read first so that they could read it individually within their groups. While other students read the article, the females either had their heads down and were napping, or were filing their nails and talking. When it was time for the lab, the females got up for the hands-on lab, but worked quickly and sat back down and slept while the teacher led a discussion on the electromagnetic spectrum. This sort of behavior continued throughout the four weeks, especially when the females participated in the quiz feedback conversations. For instance, when observing the videotapes of the females participating in the quiz feedback conversations, the females spent at most, five minutes engaged in discussion. However, because real and lasting changes in motivation take a long time, it is not a surprise that the females did not illustrate changes in interest during the four-week period.
The Impact of the Curriculum and Assessment Materials on the High Interest, Mostly High Performing Males

Changes in the males’ performance, strategy use, conceptual understanding, self-regulation, and motivation as a function of the *Astronomy Village* curriculum are reported below. In general, the males’ performance improved, as did their self-regulatory skills. However, their already high motivation and conceptual understanding stayed stable across the four weeks, while their strategy use became slightly worse.

*Changes in Performance*

The males improved their exam scores from the pre-exam to post-exam. There were 11 items that were the same from the pre to post exam. Male 1 received a 6.0 out of 11 on the pre-exam and a 10.0 out of 11 on the post-exam, improving his score by four points. Male 2 received a 10.0 out of 11 on the pre-exam and an 11.0 out of 11 on the post-exam, improving his score by one point. Male 3 received a 10.0 out of 11 on the pre-exam and a 10.0 out of 11 on the post-exam, with no increase in his score. The males’ average pre-exam score was 8.67 out of 11 items correct, while their average post-exam score was 10.33 out of 11 items correct (Table 4). Of the 11 items, the males’ exam score increased by an average of 1.66 points. Given that the pre-exam scores were so high, there may have been a ceiling effect for this group.

The males also made slight gains in scores from the pre to post test. There were 29 items on the pretest and posttest. Male 1 received a 15.0 out of 29 on the pretest and an 18.0 out of 29 on the posttest, improving his score by three points. Male 2 showed no improvement on the test. He received a 19.0 out of 29 on the pretest and a 19.0 out of 29 on the posttest. Male 3 also showed no improvement on the test and received a 19.0 out of 29 on the pretest and a 19.0 out of 29 on the posttest. The males’ average pretest score was 17.67 out of 29 items correct, while
their average posttest score was 18.67 out of 29 items correct (Table 4). Therefore, of the 29 pre-post test items, the males’ test score increased by an average of 1.0 point.

The males’ high score on the pre-exam and relatively high score on the pretest (compared to those of the females and entire class) illustrated that they began the implementation with a good deal of prior knowledge about astronomy. Compared to the gains of the entire class and to those of the low interest females, on the exam, the males had an average gain of 1.34 points lower than that of the females (females’ average pre-exam score: 6.0; females’ average post-exam score: 9.0; average gain: 3.0), and an average of .59 points lower than the average gain of the entire class (class’s average pre-exam score: 7.17; class’s average post-exam score: 9.42; average gain: 2.25). On the test, the males received an average gain equal to that of the females (females’ average pretest score: 14.67; females’ average posttest score: 15.67; average gain: 1.0), and scored an average gain of .15 points higher than that of the entire class (class’s average pretest score: 15.29; class’s average posttest score: 16.14; average gain: .85). Thus the males’ high prior knowledge caused their exam gains to be less than that of the females and the class as a whole, and their test gains to be equal to that of the females and only slightly higher than that of the entire class.

**Problem Solving Strategies**

Logbooks were collected from the males to assess their problem solving strategies. Problem solving was also assessed via the videotapes of the males participating in feedback conversations over their quizzes during the four weeks of the study. The males’ problem solving strategies as assessed by the logbooks are first described followed by a description of the males’ problem solving strategies while participating in the quiz feedback conversations.
Examination of Logbooks for Problem Solving Strategies. The logbook for the fourth week was not collected from the teacher, and as a result, the logbooks from only the first three weeks were used to examine the males’ problem solving strategies. For each week, problem solving strategies were analyzed and categorized as topic sentence, guessing, and summarization strategies. These strategies were coded for each suggested activity (suggested activities included a subset of activities in an investigation suggested to students as most useful for completion) in the logbook for which students were asked to describe the main idea of the activity. Changes in strategy use were examined across the three weeks that the logbooks were collected.

Based on the logbooks, the males began using less expert problem solving strategies with the passing of each week. During the first week, students completed the investigation Stellar Nurseries. For this week, three of the seven suggested activities, the lecture “Star-Forming Regions,” the article “Introduction to the Electromagnetic Spectrum,” and the article “Multiwavelength Astronomy” required students to describe the main idea of the activities. Of these three activities, the males completed two of the activities, the lecture and the “Introduction to the Electromagnetic Spectrum” article. For each activity, the males were required to write three sentences describing the main idea of the activity, for a total of six sentences to be written. To describe the main ideas successfully, the males would need to summarize information from the lecture and article. The males used only the summarization strategy for the lecture, and used the summarization strategy twice and the topic sentence strategy once for the article. Thus, the males used the summarization strategy for five of the statements and used the topic sentence incorrectly for one of the statements.

During the second week, students completed the investigation Search for Nearby Stars. Four out of the nine suggested activities required students to write three sentences to summarize
the main idea of the activity, for a total of 12 sentences to be written. These activities included
the lecture “Searching for Nearby Stars,” the article “Brightness of Stars,” the article “Distances
to Nearby Stars,” and the article “A Grand Tour of the Universe.” For the lecture, the males only
used the summarization strategy. Below is the males’ response to the lecture “Searching for
Nearby Stars:”

Write 3 sentences about the main idea of this lecture:

Some stars that are brighter can actually be very far away, because stars bright range
varies. Astronomers don’t use brightness to measure the distance of star, but they use
parallax. Astronomers are searching for the nearest stars because they teach us about our
position in the solar system.

Here the males’ use of the summarization strategy allowed them to illustrate and comprehend the
main idea of not only the lecture, but the entire investigation. For the article “Brightness of
Stars,” the males used the summarization strategy once, and used the topic sentence strategy
incorrectly twice. For the article “Distances to Nearby Stars,” the males again only used the
summarization strategy. For the article “A Grand Tour of the Universe,” the males used only
used the guessing strategy in that they only wrote down two statements, both of which were
composed of incorrectly guessed ideas. In all, the males used the summarization strategy seven
times, the topic sentence strategy incorrectly twice, the guessing strategy twice, and failed to
complete one statement.

During the third week, students completed the Variable Stars investigation. In the
Variable Stars investigation logbook, three of the seven suggested activities required students to
write three sentences to summarize the main ideas. These activities included the article “Variable
Stars,” the article “Candles to Light the Night,” and the lecture “Variable Stars.” The males only
completed two of the three activities including the lecture and the “Candles to Light the Night” article. For the article, the males used the topic sentence strategy incorrectly twice, and the guessing strategy one time. For the lecture, they used the guessing strategy once, the topic sentence strategy incorrectly once, and the summarization strategy once.

Table 5 includes a summary of the males’ use of the different strategies when completing the logbooks. Because the males worked in groups to complete the logbooks, the strategy of the group is always reported. The table shows that with the passing of each week, the males’ used the summarization strategy less often and the topic sentence and guessing strategy more often. The males’ use of the summarization strategy decreased from 83% during the first week to 58% during the second week to 17% during the third week. The males’ use of the topic sentence strategy (used incorrectly) increased from 17% during the first and second week to 50% percent during the third week. The males’ use of the guessing strategy also increased from 0% during the first week to 17% during the second week to 33% during the third week. It is unclear why the males began to shift their strategy use, and use poorer strategies. However, it may be that they got bored or tired of the logbooks, and felt it would be easier to just guess or copy sentences from the text.

*Examination of the Quiz Feedback Conversations for Problem Solving Strategies.*

Videotapes of the males as they participated in the quiz feedback conversations were also scored for problem solving strategies including the topic sentence strategy, the summarization strategy, and the guessing strategy. More specifically, these strategies were coded as students participated in the segment of the feedback conversation where they received the answer explanations. The males were observed to see how they used the answer explanations to come to a final consensus
response for the quiz questions. Because the males worked in groups during the feedback conversations, the strategy of the group is always reported.

The males consistently used the summarization strategy throughout the four weeks while engaging in the feedback conversations. The males used the answer explanations to summarize and form an understanding of the concepts while trying to reach a final consensus on the quiz questions. Thus, they never used the topic sentence or guessing strategy during the feedback conversations.

**Conceptual Understanding**

The males’ use of the summarization strategy appeared to help their conceptual understanding. Conceptual understanding was assessed in two ways. First, it was assessed based on the males’ logbook responses for the thought questions. These thought questions were different questions from those asking the students to write the main ideas of the activities. Instead, the thought questions asked students to think hypothetically about the concepts they had learned. Second, conceptual understanding was assessed based on the students’ final collective responses to the questions on the quizzes asking students to explain their understanding of the concepts. These responses were observed as the males participated in the quiz feedback conversations. Because the students completed the logbooks as a group, and when engaging in the feedback conversations, the students were instructed to review the answer explanations to come to a final group consensus, it was the conceptual understanding of the group that was of interest.

*Examination of Logbook Thought Questions for Conceptual Understanding.* When completing the thought questions in the logbooks, the males provided responses that suggested an excellent ability to think hypothetically about the concepts they were learning. The males’ correct answers on the two out of three thought questions they completed were comprised of
ideas that indicated that they had formed the conceptual understanding needed to apply their
learning to authentic and abstract situations. Their responses indicated that they had summarized
the main points of the text (the text of the activities requiring students to write main ideas) in a
way that provided them with the conceptual understanding needed to think hypothetically about
the concepts.

*Examination of the Quiz Feedback Conversations for Conceptual Understanding.*

Conceptual understanding was assessed based on the students’ final group consensus responses
to the questions on the quizzes asking students to explain their understanding of the concepts.
More specifically, each quiz usually consisted of one or two questions divided into parts A and
B, with part A requiring only a short answer, and part B requiring a further explanation of part A.
It was the responses to part B (except for item 1b on the first quiz) that were scored for
conceptual understanding. The males were always able to come to a correct final answer for part
B of the questions.

It may be that the males’ consistent use of the summarization strategy during the
feedback conversations, and during the first and second week logbooks may have assisted their
conceptual understanding (or was indicative of it). The males were always able to provide
correct responses to the logbook thought questions requiring them to think hypothetically about
the concepts they had learned. The males’ deeper conceptual understanding of the concepts was
likely tied to their use of the summarization strategy during the logbook activities asking for
main ideas. Furthermore, the primary use of the summarization strategy when using the answer
explanations during the feedback conversations was accompanied by the males’ better
conceptual understanding in the form of correct answers to items on part B of the quizzes.
Overall, based on the both the logbooks and the quiz feedback conversations, the males’ conceptual knowledge was consistently high throughout the four weeks.

Changes in Self-regulation

Self-regulation was assessed in two ways. First, self-regulation was assessed by examining the logbooks and calculating the number of activities the males completed in the logbook each week to see if the males were increasingly self-regulating their learning by completing more activities. Second, the videotapes of the males engaging in the feedback conversations were examined for self-regulation. The videos were examined to determine whether the males were increasingly reflecting on, monitoring, or questioning their thinking, and how their statements influenced and reflected their strategy use.

Examination of Logbooks for Self-regulation. Self-regulation was calculated by summing the number of activities students completed in the logbooks each week. The male group improved in their self-regulation over the four-week period. During the first week, the males failed to complete three of the seven suggested activities. During the second week, the males failed to complete three of the nine suggested activities. During the third week, the males only failed to complete one of the seven suggested activities. Therefore, by the third week, the males were completing more activities than the first week.

Examination of Videotapes of the Feedback Conversations for Self-regulation. The videotapes of the males participating in the feedback conversations during the four-week period were examined for metacognition. Evidence of metacognition included behaviors and verbalizations where the males were reflecting on, monitoring, or questioning their thinking.

For week one, eight metacognitive statements were recorded. All of the occurrences included statements that indicated that the males were monitoring and questioning their
understanding of the concepts. During the second week, nineteen metacognitive statements were recorded. The variety of statements such as “I don’t really understand,” “The teacher did that example,” “He did that in Apollo 13,” and “pretty much what Astronomy Village was talking about” illustrated that they were questioning what they knew and reflecting on previous activities and examples.

During the third week, twenty-seven metacognitive statements were recorded. The males were having trouble understanding Cepheid variable stars. As a result, most of their statements illustrated their struggle in trying to understand the concept. The statements of the males, primarily “Alex,” who was desperately trying to make sense of Cepheid stars, included “It doesn’t make sense to me,” “I don’t understand what he’s doing,” “I understand what he’s doing but I already know that,” “To know what a Cepheid variable star is, is not simple,” and “I’m stumped man.” During the fourth week, ten metacognitive statements were recorded. The number of metacognitive statements most likely decreased during this fourth week because the quiz was not very complex. Furthermore, the males’ statements of “It’s on that video,” and “I remember,” illustrated that they were able to reflect back and relate the quiz questions to the activities they had completed earlier in the week.

Overall, the males displayed high metacognitive skill. This was especially true when they were having problems understanding the material as they kept monitoring and questioning their understanding. Their statements appeared to reflect their use of the summarization strategy in that they wanted to tie what they were learning to what they already knew in order to form an overall understanding. The males’ metacognitive statements also appeared to influence their strategy use during the feedback conversations in that once the males recognized they had a
problem understanding the concepts, they tried to continue to discuss and use the answer explanations to summarize and form an understanding of the concepts.

*Teacher Impact on Student Problem Solving*

The videotapes were also examined to see how the teacher’s role in facilitating the feedback conversations during the third and fourth weeks influenced the males’ problem solving strategies. Although the teacher did scaffold these males during the third and fourth quiz feedback conversations with questions about their responses to the quizzes in a way that encouraged them to keep discussing and reflecting on their ideas, he did not facilitate them in a way to lead their discussions towards the right understandings. For instance, during the third week, the males were unsure of how Cepheid variable stars differed from binary stars. Below is the males’ (“Alex,” “Jason,” and “Peter”) struggle to understand Cepheid variable stars and their interaction with the teacher while trying to understanding the concept.

**Male group’s discussion over Cepheid variable stars:**

A: I put the way the light changes.

J: I put that Cepheid stars (pause) their brightness-their changes are easy to predict

J: That-I don’t know how that’d help you. I’m not really sure on that one.

P: I said the **distance stays the same** (pause) which. (pointing pen at J) Did you make stuff up?

A: I put the way the light changes.

Um, I guess it would be the same as yours, like I guess if the light doesn’t change a lot then it stays pretty constant **unless light has to do with distance**.

P: I thought it would be like the **star stays there** but the brightness changes.

A: **Right.**
Instead of moving further and closer to you. At this point, the males had come to the correct conclusion that the variation in the brightness of the star did not have to do with the movement of the star. The teacher, who then tried to facilitate the discussion was unsuccessful.

**Male group’s interaction with teacher:**

T: What did we do on the second part of the question?

A: We got it wrong.

T: You got it wrong, how do you know it’s wrong (laughs)

A: (laughs) Cause we can’t come up [with a decent] answer.

J: [An answer]

T: (looks at P’s paper a bit). Alright we know that the Cepheid or Cepheid star is a variable star now it’s not a binary star it’s a single star.

A: Right.

T: And they’re showing us that it’s getting lighter and brighter and lighter and brighter and this one does so in what- a cycle of about 6 days from peak to peak or from valley to valley. Now how might that help us with distance.

J: Um, (pause) you can compare it to other stars I guess um.

T: You know the light bulbs that have 3 different switches and it’ll go from, do you have a light at home

A: It’s like a touch lamp, it goes from dim to medium to bright?

T: Yeah and it goes from dim to medium or medium to sort of bright. Well if you were reading a book there and you put it on dim you would have to get pretty close to read your book good, wouldn’t you. But if you put it on the brightest setting could you get farther away?
A: Yeah.

At this point in their exchange, the teacher engaged the males in a discussion about the relationship between distance and brightness of the Cepheid stars, which “Alex” had evoked earlier in their group discussion. The teacher used the analogy of a dimmer switch to drive home his point, but did this with no real knowledge of how far the male group had come in reasoning through this problem or the relationship between light and distance. The remainder of this excerpt follows.

T: So does that brightness and distance kind of have some sort of relationship?

A: Yeah.

T: That’s sort of what they’re kinda using here I think since there’s a variation in light and you know that light and distance are related you might can actually work backwards.

A: **So it’s saying that the star is moving.** So every 6 days from each peak it’s at the same spot it was 6 days before.

T: Well pretty much but it’s

A: Like roughly.

Here, Alex is confused after the teacher’s analogy of the dimmer switch to explain the distance and brightness relationship. Alex now incorrectly believes that the reason the star’s magnitude changes is due to the fact that its distance is changing. Below, the teacher attempts to redirect Alex’s misconception:

T: If I’m right here and I take two steps away from you will I significantly change distance from you? If I’m 100 miles away from you and I take two steps away from you it wouldn’t change the distance much. So probably in that 6 day period do you think that star’s really much farther or much closer to us.
A: No.

T: So I don’t know if it’s the distance of the star but the brightness can help us keep thinking about that, think about that dim light.

(teacher walks away)

A: So he’s saying that every 6 days, the star moves close to us and then back every 6 days. That’s what I’m getting at.

J: Yeah.

A: Which still doesn’t make sense because the further away it is the brighter it should not be.

J: Yeah I don’t know the star wouldn’t move much in 6 days.

P: It has to have something to revolve around.

A: I’m stumped man.

A: I don’t understand. I understand what he was doing, but I already know that. I got that part. (long pause) Well to know what a Cepheid variable star is, is not simple.

The teacher’s explanation led the males to the incorrect understand of Cepheid variable stars. Initially, the group had agreed that the star is stationary and the magnitude changes. After the teacher’s intervention, Alex was back to believing, incorrectly, that the star’s change in magnitude is due to its movement. Thus the teacher was unable to facilitate the males in coming to a conclusion about Cepheid variable stars, and in fact led the students to an incorrect understanding of the concept.

Although the teacher was facilitating the males’ discussion over the same quiz question and with the same example of the dimmer light switch that he used with the low interest females, his facilitation was quite different. Unlike the known-answer questions he used to facilitate the females learning, with the males, the teacher was more unclear in his facilitation. He never led
the males to an answer, but instead left them with “So I don’t know if it’s the distance of the star but the brightness can help us keep thinking about that, think about that dim light,” and encouraged them to keep discussing. The teacher’s different approach towards the two groups may be because he identified the male group as being high achieving and the female group as being low achieving, thus scaffolding the females more. The teacher’s interactions with the males may have contributed to their use of the summarization strategy by encouraging them to keep discussing and reflecting on their ideas in order to form an understanding of the concepts. When the males received the answer explanations, they used the answer explanations to summarize and discuss the ideas to form a final correct understanding of Cepheid variable stars and their regularity in brightness being useful for measuring distance. Therefore, their use of the summarization strategy helped them form a good conceptual understanding of Cepheid variable stars. However, because the answer explanations did not address the males’ question about the reason Cepheids change their brightness, the males were still confused about this aspect of Cepheid variable stars.

Observations of Motivation

High interest males differed from their lower performing female counterparts in that they showed high interest in the topic at the beginning of the program. This high interest, which was assessed through classroom observations of the males engaged in activities and the timing of the males’ engagement in the feedback conversations, continued throughout the implementation.

When completing the activities, the males appeared more interested than the group of females and any of the other groups of students in the classroom. For instance, during the first day of the implementation, students were given a lab and an article to complete. When observing the males complete the lab, they appeared very engaged in the lab as they worked together using
all the suggested light sources needed to complete the lab, and also went to an overhead light source as an extra resource for their lab. This sort of behavior continued throughout the four weeks, especially when the males participated in discussion over the quizzes. When observing the videotapes of the males engaging in the feedback conversations, the males were persistent in their discussions, kept discussing when they did not understand specific concepts, and continued to discuss until the teacher concluded the feedback conversations.

A High Interest, Yet Low Performing Male

The group of males and group of females were formed based on interest. However, it was found that the group’s interest strongly corresponded to their achievement, with achievement being the students’ previous semester astronomy grade. Of the six females in the class, the three low interest females had received the lowest grades. Of the nine males in the class, two of the high interest males received the highest grades, while the third male fell among one of the lowest grades of the nine males. Therefore, there was one male (male 1 as listed in the changes in performance section), “Alex,” in the high interest male group whose interest did not correspond to his performance. Alex was observed while participating in the feedback conversations over the quizzes in order to understand why a male with high interest in astronomy would be performing so poorly in the class, and whether his strategy use was a factor contributing to his low performance.

Based on observations from the videos of the males engaging in the quiz feedback conversations, Alex was clearly the leader of the high interest male group. He began the conversations, made sure everyone in the group understood the concepts on the quiz before moving to the next question, kept the discussion moving, and was the most persistent in trying to discuss and understand the material. Despite this high motivation and participation, of the three
males, he had the greatest number of incorrect initial responses on his quiz. Therefore, when the males first stated and explained their responses on the quizzes, of the 12 possible questions on the four quizzes, Alex had five incorrect responses. Jason had two incorrect responses, while Peter had no incorrect responses. However, despite his many incorrect responses, Alex always made sure that he understood what mistakes he made and why. He questioned his group members and used the discussions and answer explanations to summarize and form an understanding of the concepts. Therefore, his strategy use was the same as the other males in his group in that he also used the summarization strategy during the feedback conversations.

Despite Alex’s many incorrect responses on the quizzes, he had the highest gains on both the exam and test. While Alex had a four point gain on the exam and a three point gain on the test, Jason (male 2 as listed in the changes in performance section) had a one point gain on the exam and no gains on the test. Finally, Peter (male 3 as listed in the changes in performance section), had no gains on the exam or test. Therefore, Alex appeared to benefit the most from the implementation.

Overall, it appears that Alex was lower performing because of his incorrect responses on assignments and tests. Although Alex was motivated, he needed the opportunity to practice this motivation in a way that would allow him to discuss, reflect on, and refine his ideas. However, the regular structure of the classroom rarely provided students with an opportunity for collaboration. When Alex did have the chance to engage in discussion during this implementation, the teacher was often unable to facilitate in a way that was effective. For instance there were many times when Alex appeared frustrated because the teacher did not understand what he was asking (“I understand what he’s doing, but I already know that”) and was unable to facilitate Alex in a way to lead his discussions towards the right understandings.
Therefore, a different context where discussions and more in-depth teacher facilitation are prevalent could help Alex increase his performance in science. However, it did not appear that his strategy use was inhibiting his performance.

Classroom Observations and Results

Below is an analysis of the implementation as it affected the entire class. Results on the entire class are provided in order to present a context in which the two focus groups worked. A description of classroom performance gains and difficulties that occurred with the implementation is presented below. An examination of exam and test scores for the entire classroom indicated significant gains in content learning as measured by the exam and non-significant gains in both content and inquiry learning as measured by the test. There were also a number of difficulties that emerged with the enactment of the activities and feedback conversations. These learning gains and implementation difficulties are described in detail below.

Performance Data

Pre and post exam and test scores for the entire class were collected and analyzed (Table 6). On the 11 items that were the same on the pre and post exam, the 12 students who took both administrations of the exam received an average score of 7.17 out of 11 on the pre-exam and an average score of 9.42 out of 11 on the post-exam, increasing their exam score by an average of 2.25 points. For the 29 test questions, the 14 students who took both administrations of the test received an average score of 15.29 out of 29 on the pretest and an average score of 16.14 out of 29 on the posttest, increasing their test score by an average of .85 points. Repeated measures analyses indicated significant exam gains \( F(1,11) = 18.43, p<0.001 \). The test gains \( F(1,13) = 3.21, p<0.097 \) were not significant.
The pre and post test was also analyzed for inquiry data (Table 7). Pre-post scores on the four astronomy inquiry items, as well as the “inquiry triangle” items were examined to see how the implementation affected the students’ ability to engage in inquiry. There were 14 students who took both administrations of the test. On the four astronomy-content inquiry items, the 14 students received an average score of 3.64 out of 4 on the pretest and an average score of 3.71 out of 4 on the posttest, increasing their score by an average of .07 points. On the three inquiry triangle questions, the 14 students received an average score of 1.86 out of 3 on the pretest and an average score of 2.14 out of 3 on the posttest, increasing their score by an average of .28 points. There was a ceiling effect on both the astronomy-content inquiry items and the inquiry triangle items, leaving little room for gains in inquiry learning.

Difficulties with the Implementation of Astronomy Village

Activities. Two activities in the “Variable Stars” investigation posed some difficulty for the students. The first problem related to a disconnect in the curriculum. Specifically, the hands-on lab, “Cepheid Variable Interpretation Guide,” required a brightness count from an activity not included in the curriculum. Thus the students did not have the data needed to make the required calculations. The second problem related to a technology issue. The data analysis activity called “Image Processing Computer: Studying Cepheids and Light Curves” required images that failed to open. In addition, during interviews, the teacher mentioned that the students completed each day’s activities very quickly, and that it would be useful to add additional activities to the curriculum.

Feedback Conversations. Despite assigning a participation grade to encourage students to engage in the feedback conversations, it was difficult to get the students involved in discussion. Prior to the implementation, the students had worked in a teacher-centered learning environment
in which the teacher lectured while the students listened. When the teacher was not leading a discussion, the students would sit and complete class work or would work on assigned homework quietly on their own. Within this context, the students were rarely provided with the opportunity to interact. The seven months of working in a teacher-centered learning environment most likely made the transition to a student-centered, collaborative learning environment difficult.

Possibly adding to the students’ resistance to engaging in discussion was that some of the students found it uncool or nerdy to show interest in or to discuss the astronomy concepts. For instance, students were encouraged to take a copy of the *Astronomy Village* CD home so that they could look over the different activities, images, and simulators in the software. Only two students took the CD home, with one stating that he felt ‘embarrassed’ for taking the CD. Furthermore, the group of high interest males who were acknowledged by the instructor for discussing and knowing about the curricular concepts, referred to themselves as the ‘Galactic Geeks,’ thus expressing an understanding of their intellect and the accompanying stereotype. These attitudes made it difficult to engage students in discussion, but are not uncommon in many high school courses. Because the students were not used to engaging in collaborative learning, and because it was ‘uncool’ to show interest or actively participate in the discussions, students rushed through the feedback conversations. This was especially true when the teacher did not facilitate the discussions. Teacher facilitation during the third and fourth quiz feedback sessions increased the students’ engagement in the discussions.

Assigning a grade for the post-exam inhibited the exam feedback conversations. Because the students received their exams with a grade on them, most students reviewed the exam hastily, not reading through the answer explanations, especially for the problems marked correct.
Overall, students discussed their initial exam responses for approximately nine minutes, coming to a preliminary consensus on the questions, and then three minutes reading and reviewing the answer explanations in order to come to a final consensus for each question.
Table 1: Female Group’s Exam and Test Scores.

<table>
<thead>
<tr>
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<th>Pre-exam</th>
<th>Post-exam</th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female 1</td>
<td>3.0</td>
<td>8.0</td>
<td>12.0</td>
<td>12.0</td>
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<tr>
<td>Female 2</td>
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<td>10.0</td>
<td>14.0</td>
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<td>Female 3</td>
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<td>N/A</td>
<td>18.0</td>
<td>19.0</td>
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<td>Average</td>
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<td>9.0</td>
<td>14.67</td>
<td>15.67</td>
</tr>
</tbody>
</table>

Table 2: Female Group’s Strategy Use when Completing the Logbooks.

<table>
<thead>
<tr>
<th>Week</th>
<th>Number of Activities Completed</th>
<th>Count of Summarization Strategy</th>
<th>Count of Topic Sentence Strategy (used incorrectly)</th>
<th>Count of Guessing Strategy</th>
<th>Number of times the topic sentence strategy was used correctly</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>0/6 (0%)</td>
<td>3/6 (50%)</td>
<td>1/6 (17%)</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>5/12 (42%)</td>
<td>3/12 (25%)</td>
<td>2/12 (17%)</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>4/6 (67%)</td>
<td>1/6 (17%)</td>
<td>0/6 (0%)</td>
<td>1</td>
</tr>
</tbody>
</table>

Note. The topic sentence strategy (used incorrectly) and guessing strategy were considered to be poor strategies, while the summarization strategy was a strategy that was expected to lead to a summary and overall understanding of the main ideas. The topic sentence strategy used correctly was not considered to be a good or bad strategy and could only be used correctly for a total of 11 out of 24 possible statements.
Table 3: Female Group’s Strategy Use when Engaging in the Feedback Conversations.

<table>
<thead>
<tr>
<th>Quiz</th>
<th>Number of items on quiz</th>
<th>Count of Summarization Strategy</th>
<th>Count of Topic Sentence Strategy (used incorrectly)</th>
<th>Count of Guessing Strategy</th>
<th>Number of times the topic sentence strategy was used correctly</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>0/3 (0%)</td>
<td>0/3 (0%)</td>
<td>2/3 (67%)</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>2/4 (50%)</td>
<td>0/4 (0%)</td>
<td>2/4 (50%)</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>0/2 (0%)</td>
<td>0/2 (0%)</td>
<td>0/2 (0%)</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>1/3 (33%)</td>
<td>0/3 (0%)</td>
<td>2/3 (67%)</td>
<td>0</td>
</tr>
</tbody>
</table>

Note. The strategies here are based on how the students used the answer explanations to come to a final consensus for the quiz questions. The topic sentence strategy (used incorrectly) and the guessing strategy were considered to be poor strategies, while the summarization strategy was a strategy that was expected to lead to a summary and overall understanding of the main ideas. The topic sentence strategy used correctly was not considered to be a good or bad strategy, and could only be used correctly a total of three times for all four quizzes.

Table 4: Male Group’s Exam and Test Scores.

<table>
<thead>
<tr>
<th></th>
<th>Pre-exam</th>
<th>Post-exam</th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male 1</td>
<td>6.0</td>
<td>10.0</td>
<td>15.0</td>
<td>18.0</td>
</tr>
<tr>
<td>Male 2</td>
<td>10.0</td>
<td>11.0</td>
<td>19.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Male 3</td>
<td>10.0</td>
<td>10.0</td>
<td>19.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Average</td>
<td>8.67</td>
<td>10.33</td>
<td>17.67</td>
<td>18.67</td>
</tr>
</tbody>
</table>
Table 5: Male Group’s Strategy Use when Completing the Logbooks.

<table>
<thead>
<tr>
<th>Week</th>
<th>Number of Activities Completed</th>
<th>Count of Summarization Strategy</th>
<th>Count of Topic Sentence Strategy (used incorrectly)</th>
<th>Count of Guessing Strategy</th>
<th>Number of times the topic sentence strategy was used correctly</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>5/6 (83%)</td>
<td>1/6 (17%)</td>
<td>0/6 (0%)</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>7/12 (58%)</td>
<td>2/12 (17%)</td>
<td>2/12 (17%)</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1/6 (17%)</td>
<td>3/6 (50%)</td>
<td>2/6 (33%)</td>
<td>0</td>
</tr>
</tbody>
</table>

Note. The topic sentence strategy (used incorrectly) and guessing strategy were considered to be poor strategies, while the summarization strategy was a strategy that was expected to lead to a summary and overall understanding of the main ideas. The topic sentence strategy used correctly was not considered to be a good or bad strategy and could only be used correctly for a total of 11 out of 24 possible statements.

Table 6: Classroom Exam and Test Scores.

<table>
<thead>
<tr>
<th>Curriculum-oriented Exam (11 questions)</th>
<th>Pre Mean (SD)</th>
<th>Post Mean (SD)</th>
<th>Average Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.17 (2.04)</td>
<td>9.42 (1.78)</td>
<td>2.25</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Standards-oriented Test (29 questions)</th>
<th>Pre Mean (SD)</th>
<th>Post Mean (SD)</th>
<th>Average Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.29 (3.36)</td>
<td>16.14 (2.66)</td>
<td>.85</td>
<td></td>
</tr>
</tbody>
</table>

Table 7: Classroom Learning Gains on the Inquiry Items.

<table>
<thead>
<tr>
<th>Astronomy Inquiry Items</th>
<th>Pre</th>
<th>Post</th>
<th>Average Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.64</td>
<td></td>
<td>3.71</td>
<td>.07</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Inquiry Triangle</th>
<th>Pre</th>
<th>Post</th>
<th>Average Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.86</td>
<td></td>
<td>2.14</td>
<td>.28</td>
</tr>
</tbody>
</table>
CHAPTER 4

DISCUSSION

Classroom observations, videotapes of the two focus groups engaged in discussion, logbooks from the two focus groups, self-reports from all of the students, and in-depth interviews with the teacher indicated that the *Astronomy Village* implementation could be revised in several ways to improve the performance of the two focus groups, as well as the entire class. First, a discussion of ways to help the low interest, low performing females is provided, followed by a discussion of ways to assist the high interest, mostly high performing males. Finally, recommendations for how to tackle the problems experienced by the entire class are provided. It was expected that any lessons learned through this implementation would not only apply to this implementation context, but could be applied to different learning environments.

*Improving the Performance of the Low Interest, Low Performing Females*

Over the four-week period, the females began to improve in their problem solving strategies. However, this improvement in strategy use was evident only in the logbook entries. The fact that the females continued to use the guessing strategy throughout the four weeks during the feedback conversations suggests that they were unaware of their strategy use and unable to transfer it out of the context of the logbooks. This is in line with the work of Goldin-Meadow and Singer (2003) showing that gestures that are inconsistent with verbal reports are frequently evidence of emerging strategies. From this perspective, the females appeared to be developing the summarization strategy, but the strategy use was not developed enough for them to be aware of its use or to transfer the strategy to related contexts. Research by Church and Goldin-Meadow
(1986) suggests that with appropriate scaffolding, the females may consolidate the acquisition of the summarization strategy. Thus the low performing females need more teacher support to help them shift to the routine use of the summarization strategy.

One way the teacher can help the low performing females shift to the use of the summarization strategy is to explicitly teach the summarization strategy. Also, the teacher should observe what the females are focusing on in their writings. The teacher, who collected the logbooks for a grade, graded the logbooks for completion rather than quality of the entries. Therefore, the females did not know they were using poor strategies to summarize the main ideas. Finally, students with poor strategic skills might also benefit from working with higher achieving students who may question their strategies and encourage them to do the same.

Although the females’ conceptual understanding and motivation did not appear to change much over the four-week period, it is likely that their low motivation, poor performance, poor conceptual understanding, and poor problem solving strategies were linked in that learning is a function of all four factors. By helping low performing students improve their problem solving strategies, conceptual understanding, achievement, and motivation may also improve. However, the implementation of AV may have been too short to see changes in conceptual understanding and motivation that might have emerged over time with better strategic performance.

**Improving the Performance of the High Interest, Mostly High Performing Males**

Unlike the females, the males mainly used the summarization strategy throughout the four weeks. Despite this, their problem solving strategies while using the logbooks decreased with the passing of each week as they began using the summarization strategy less often and the topic sentence and guessing strategies more often. The fact that the males continued to only use the summarization strategy during the feedback conversations indicated that they were not
becoming less advanced in their problem solving strategy use, but rather were becoming bored with the logbooks. Second, the males entered the program with very high pre-exam scores, suggesting that they knew much of the information before the start of the implementation. Therefore, in its current form the Astronomy Village implementation is too easy for students comprising the upper end of the continuum and is more useful for lower performing students.

*Lessons Learned for Improving the Performance of all Students in the Classroom*

**Teacher Involvement**

The impact of the program might improve with more and earlier involvement of the teacher. For instance, although the teacher was given a copy of all the assessments and answer explanations, he admitted to not looking over the quizzes and answer explanations until administering them. More meetings with the teacher would allow the teacher to become more involved in designing and reviewing the quizzes and answer explanations, making them more valuable and at the optimal difficulty level for his or her students. Teachers may become more involved once the curriculum is no longer experimental with its use directed by researchers.

Teachers also need to be explicitly taught how to promote strategy use and discussion. During the first two weeks of the quiz feedback conversations, the teacher prematurely put much of the control of the structure and content of the conversations in the hands of the students. After the teacher was encouraged to facilitate these discussions during the third week, conversations increased in duration. In addition to facilitation during the feedback conversations, having teachers more closely direct students during the activities would encourage students to participate in more valuable content and inquiry processing. Promoting and facilitating the use of the summarization strategy would not only increase the duration, but the quality of the students’ discussions, as students would focus on forming main ideas rather than finding topic sentences or
coming up with estimates or guesses. This facilitation of strategy use and discussion would ultimately improve understanding and performance.

**Improved Assessments**

Although students increased the amount of time they spent involved in feedback conversations, students never spent more than five minutes reading and discussing the answer explanations. To deal with this problem, the teacher suggested adding more questions to the quiz, while at the same time, making the quizzes and answer explanations more difficult. He felt that making the quizzes and answer explanations longer and more complex would engage students in longer and more involved conversations. McCaslin and Hickey (2001) describe how Vygotsky would change a task to “increase its frustrating potential, thus requiring self-directive speech” (p. 239). Similarly, making the quizzes and answer explanations more difficult or “frustrating” than students are accustomed to may increase group discourse as students further discuss and question the concepts.

Another recommended adjustment is to modify the format of the exam feedback. The day after the post-exam, students received their grades on the exam. Students rushed through the exam feedback conversations, presumably because they had received their final grades. In the future, grades might not be indicated on the exam itself. A useful idea would be to record students’ final grades, but return the exams with no grade, allowing the students to discuss their answers to find any mistakes they may have made. Extra points could be given to students accurately finding their errors on their exam.

Another way to modify the exam, which will likely increase performance gains, is to only assess new content. The teacher mentioned that the first investigation, *Stellar Nurseries*, which was a review of the content that students had covered earlier in the semester, was a useful
transition into the new material and environment in which they would be participating. However, because students had already learned about the electromagnetic spectrum, many of the students were able to correctly answer questions about prisms and waves on the pre-exam, causing smaller gains from the pre to post exam. To improve exam gains, only investigations that involve an exploration of material in which students have not already been exposed should be included.

To help make the test more challenging and increase performance gains on inquiry items, more difficult inquiry items should be included on the test. When examining learning gains on the four astronomy-content inquiry items, as well as the inquiry triangle items, the gains from the pre to post test were very low. This was likely due to a ceiling effect on the items on the pretest. Because it was difficult to find inquiry items from released tests and other various domains, some of the inquiry items that were included were of middle school level. Thus, in the future it would be useful to include more difficult items or refine already selected items to make them more challenging for high school students.

Another way the assessments can be improved is to add items on the quiz, exam and test assessing misconceptions. Students’ learning and performance in science is often impaired by the misconceptions that they may hold. Each of the four investigations covered a misconception (Table 8). The quizzes and answer explanations implicitly worked to help clarify the misconceptions in the Stellar Nurseries and Variable Stars investigations, and explicitly clarified the misconceptions in the Search for Nearby Stars and Search for a Supernova investigations. A useful idea for the future would be to explicitly test and describe these misconceptions in the quizzes and answer explanations. In addition, questions targeting the misconceptions could be added to the pre and post exam and test to see if the implementation helped students tackle these misconceptions.
Changes to the Curriculum, Logbooks, and Group Design

Small changes to the curriculum would help make the activities run more smoothly during the implementation. The data analysis and hands-on lab that students had problems completing should be examined ahead of time to ensure that they will be able to be completed with ease the day of class. The hands-on lab “Cepheid Variable Interpretation Guide” needed a brightness count from the “Measuring Brightness” activity in order to be completed. Therefore, in the future, the “Measuring Brightness” activity could be added to the curriculum. For the data analysis activity, “Image Processing Computer: Studying Cepheids and Light Curves,” instructions may be designed and given to the students to help them open the images needed in order to complete the activity.

The teacher reported that students completed daily activities quickly, especially those assigned for the computer lab. In the future, additional activities from each investigation could be added into the four-day period. Based on the student self-reports, students stated that they enjoyed the hands-on labs and lectures more than the other activities, and learned the most from the lectures, articles, and labs. The teacher, who mentioned several times how difficult it was to find labs in astronomy, felt that the hands-on labs were extremely useful. Therefore, when including more activities it would be useful to include more lectures, article readings, and hands-on labs. These lectures, article readings, and labs could be included from the background section of the path diagram in order to help students develop the background knowledge needed to become proficient enough in their understanding of the concepts.

In line with adding more activities to the curriculum, the teacher suggested assigning certain activities for homework so that the students would be able to complete more of each investigation. This may be useful for several reasons.
assignments in the curriculum each week, students would be completing additional activities. Furthermore, students would have more exposure to the software, and as a result, may find themselves interested in going through parts of the CD and participating in activities that were not part of the suggested activities. Finally, this would allow students who want to take the CD home to feel comfortable doing so in front of their classmates.

At the beginning of each week, a statement of problem was supposed to be administered to each group of students. However, after the first week, the teacher stopped issuing the statement of problem. Although a copy of the statement of problem was included in the second page of the logbook, it was in small print and included in the cover pages, so students skipped right past it in order to fill in their responses to the activities. In the future, the teacher should be encouraged to administer this statement to students. A statement of problem introduces an investigation, while at the same time, describes how the activities within each level of the path diagram contribute to the main theme of the investigation. This can assist students in their inquiry processing because it allows them to understand the individual tasks relative to a larger goal (Edelson, Gordin, & Pea, 1999).

Throughout the four weeks, students often complained about the size and complexity of the investigation logbooks. Although students were given a list of approximately six suggested activities to complete each week, the logbooks contained entries for all the possible activities in the investigation. Thus, a logbook might contain entries for twenty activities, but students only had to complete six. Originally, it was thought that including logbook entries for every activity would enable and encourage students to complete extra activities. However, this was not the case. The thick logbooks became confusing and students often had difficulties locating the appropriate activities. In the future, the logbooks should include page numbers and only the
suggested activities. In case students want to complete extra activities, additional blank pages can either be attached at the end of the logbook or made available through the teacher.

To help students work more effectively, the teacher also suggested changes in group size. He felt that groups of two instead of three would enable students to work more comfortably and efficiently on the computer and on different activities. Meanwhile, for the feedback conversations, he suggested combining two groups, forming groups of four so that the group would be large enough to where students would be exposed to a diversity of ideas. These more specific overall classroom changes as well as the changes suggested for the male and female group can help improve learning for all the students using the Astronomy Village software program.

This study examined gender differences in prior knowledge, performance, problem solving, conceptual understanding, self-regulation, and motivation in a group of low interest, low performing females, and a group of high interest, mostly high performing males. Furthermore, the study examined how the students’ performance, problem solving strategies, conceptual understanding, self-regulation, and motivation were influenced by the implementation of the Astronomy Village software program. Results indicated that there were significant differences in the prior knowledge, problem solving strategies, conceptual understanding, and self-regulation between the two groups. Compared to the males, the females began the implementation with less prior knowledge, and were less expert in their problem solving strategies, conceptual understanding, and self-regulation. However, the implementation helped improve the performance, problem solving strategies, and self-regulation of the females. Although the males had gains in performance and did improve in their self-regulatory skills, they began to use less expert problem solving strategies over the duration of the study. This use of less advanced
problem solving strategies, and the males’ already high pre-exam scores suggest that in its current form, the implementation of the software and supplemental curriculum and assessment materials may be too easy for students in the upper end of the continuum and might be more useful for lower performing students.

**Plans for Future Research**

Studying a group of high performing females and a group of low performing males will help make clear whether these differences are a result of gender or performance. If high performing females use similar strategies to low performing females, this would indicate that gender differences exist in the strategies males and females use. If high performing males and females use similar strategies and low performing males and females use similar strategies, this would suggest that differences in strategy use are tied to students’ performance. In either case, the next step would be to conduct research focusing on improving strategy use, and how improving strategy use influences achievement.
Table 8: Misconceptions Addressed by the Curriculum and Assessments.

<table>
<thead>
<tr>
<th>Investigation</th>
<th>Misconception</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stellar Nurseries</td>
<td>Radio waves are sound waves</td>
</tr>
<tr>
<td>Search for Nearby Stars</td>
<td>Stars that are brighter are closer</td>
</tr>
<tr>
<td>Variable Stars</td>
<td>A star’s brightness does not change in short time periods such as months, days, or seconds</td>
</tr>
<tr>
<td>Search for a Supernova</td>
<td>Our sun will explode into a supernova</td>
</tr>
</tbody>
</table>
REFERENCES


APPENDIX A

STANDARDS-ORIENTED TEST

Name:___________________________________     Date:_________________

please print your name

Astronomy Village
Test

Instructions
Read the following items carefully and mark the box next to the response that best answers the question.

Test

1  What is the big advantage of the Hubble space telescope over, say, the Mount Palomar telescope?
   □ Space telescopes are closer to the objects they observe, because they are already in space
   □ You don't have to buy real estate in space, which makes them much cheaper
   □ Space telescopes don't have to deal with the distortion caused by the atmosphere
   □ Space telescopes can be built much bigger, since gravity doesn't distort them
   □ It is always night in space

2  The range of frequencies in which electromagnetic waves occur is called the:
   □ radar
   □ electromagnetic spectrum
   □ UVB rays
   □ visible light
3 Which of the following would be the best description of light?
- It consists of a wave of energy alternately in the form of electric and magnetic energy
- It consists of a wave of energy alternately in the form of protons and electrons
- It is a sound wave which travels very quickly through the near perfect vacuum of space
- It is a form of heat that travels at extremely high speed
- It is an alternate form of gravitational energy

4 Which of the following best describes white light?
- Because white is not a color, it does not contain any wavelengths of light
- Since white is pure, it consists of only one wavelength of light
- It is actually not part of the visible part of the spectrum at all, it is merely our perception of ultraviolet light
- It is actually a mixture of all different wavelengths of light
- No astronomical object is actually “white,” this is just a perception caused by the filtering effects of our atmosphere

5 Which of the following has the highest frequency?
- Red visible light
- Yellow visible light
- Microwaves
- Radio waves
- Infrared light

6 Which of the following is NOT a color of light of the electromagnetic spectrum?
- red
- orange
- brown
- blue
- violet
7 If all the planets started out together on their trips around the sun, which one would finish the trip last?
- Jupiter
- Pluto
- Mercury
- Saturn

8 The Milky Way galaxy is to the sun as
- an ocean is to a water molecule
- an engine is to a car
- the rails are to a train
- the sun is to the Earth

9 The Andromeda galaxy is about 60,000 pc away. Could this have been figured out from parallax measurements?
- Yes
- No, because parallax only works on main sequence stars, and these are too dim to use at that distance
- No, because parallax requires measuring angles, and the angles would be too small at that distance
- No, because parallax relies on the Doppler effect, and Andromeda is not far enough away to use Doppler measurements.
- No, parallax is only used for planets, and we can't see planets at that distance

10 Dan viewed two light bulbs of equal power. Bulb A appeared dimmer than Bulb B. A possible explanation for this is that
- Bulb B is farther away from Dan than Bulb A
- Bulb A is farther away from Dan than Bulb B
- Bulb A and Bulb B are next to each other
- Bulb A and Bulb B are connected to the same battery.
When a spectrum of the galaxy M31 is taken (which contains billions of stars), it is found that there are dark lines very close to the spectral lines of hydrogen, but shifted slightly towards the blue. This tells us that

☐ M31 consists primarily of hot stars, which tend to be bluer in color

☐ M31 is moving towards us

☐ M31 is moving away from us

☐ Dust and gas between M31 and us has shifted the spectrum towards the blue

☐ M31 must consists primarily of young stars

By examining data from distant stars, astronomers can determine if a star is moving away from or toward Earth. Which of the following pieces of data would be most helpful in determining the motion of a star?

☐ The star gives off blue-white light.

☐ The star gives off mainly radio waves and X-rays.

☐ The surface temperature of the star is approximately 10,000°C.

☐ The light spectrum given off by the star is shifted toward the red

According to Kepler, where is the Sun in comparison to a planet’s orbit?

☐ It is at the center of the elliptical orbit

☐ It is on the directrix of the elliptical orbit

☐ It is at one of the two foci of the elliptical orbit

☐ It is on the elliptical orbit, at one end of the semi-major axis

☐ It is on the elliptical orbit, at one end of the semi-minor axis
14 Which of the following objects probably has substantial oceans of liquid water under the surface?

- [ ] Io
- [ ] Neptune
- [ ] Mars
- [ ] Europa
- [ ] Titan

15 Using the table below, which of the following wavelengths could be broadcast by a rock-and-roll radio station?

<table>
<thead>
<tr>
<th>Electromagnetic Waves</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Wave</strong></td>
</tr>
<tr>
<td>Gamma Rays</td>
</tr>
<tr>
<td>X Rays</td>
</tr>
<tr>
<td>Ultraviolet Rays</td>
</tr>
<tr>
<td>Infrared</td>
</tr>
<tr>
<td>Microwave</td>
</tr>
<tr>
<td>Radio Waves</td>
</tr>
</tbody>
</table>

- [ ] $10^{-12}$ meters
- [ ] $10^{-8}$ meters
- [ ] $10^{5}$ meters
- [ ] $10^{-3}$ meters
The diagram below shows the types of electromagnetic energy given off by the Sun. The Shaded Part of the diagram shows the approximate amount of each type actually reaching Earth’s surface. Which Conclusion is best supported by the diagram?

- All types of electromagnetic energy reach the Earth’s surface.
- Gamma rays and X-rays make up the greatest amount of electromagnetic energy reaching Earth’s surface.
- Visible light makes up the greatest amount of electromagnetic energy reaching Earth’s surface.
- Ultraviolet and infrared radiation make up the greatest amount of electromagnetic energy reaching Earth’s surface.

When a star is about to become a type II supernova, the number of electrons decreases radically, but the number of neutrons increases radically. How come the degeneracy pressure of the resulting neutrons is so small compared to the degeneracy pressure of the electrons?

- Degeneracy pressure is a quantum mechanical effect that affects electrons, but not neutrons.
- Degeneracy pressure exists for neutrons and electrons, but it is much smaller for neutrons because they are so much heavier.
- Electrons have electric charge and repel each other; neutrons are neutral and do not.
- The core of the star expands immensely during this stage, so that the pressure goes down.
- The degeneracy pressure doesn’t actually change, but gravity becomes much more powerful.
A white dwarf is accreting gas from its companion star. It is about to become a type I supernova. What triggers this event?

- The mass reaches the Chandrasekhar limit
- The temperature reaches the hydrogen fusion limit
- The Helium fuel runs out
- The orbit collapses and causes a stellar collision
- The protons and electrons combine to make neutrons

In the core of a star, the temperature can reach heights unknown on Earth. The process by which stars generate energy is called:

- photosynthesis
- fusion
- condensation
- radiation

Stars are born in:

- Planetary nebulae
- Molecular clouds
- Supernova remnants
- Neutron Stars
- White Dwarfs

One reason binary stars help us understand stars is because it allows us to measure the _________ of stars

- Luminosity
- Brightness
- Spectral Class/Spectral Type
- Mass
- Age
22 From the spectrum of a star, we can determine its
☐ Temperature (only)
☐ Composition (only)
☐ Velocity (only)
☐ A and C, but not B
☐ A, B, and C

23 A star is the same temperature as the Sun, but it is 9 times as luminous. How large is it?
☐ 3 times as large as the Sun
☐ 6 times as large as the Sun
☐ 9 times as large as the Sun
☐ 81 times as large as the Sun
☐ $6561 = 9^4$ times as large as the Sun

24 The Sun is only one of billions of
☐ nebulas
☐ stars
☐ galaxies
☐ quasars

25 How come there are no main sequence stars that weigh .05 times the mass of the Sun?
☐ Such light stars lose mass so fast they can't become main sequence stars
☐ They never get hot enough to even begin fusion
☐ They live such a short time, they essentially don't exist
☐ The protostar stage lasts so long, no star has even reached the main sequence yet
☐ Such stars always collapse to black holes before they can become regular stars
26 Some stars last for a trillion years or so; others are gone in a million years or so. What factor is responsible for this wide disparity?

- The velocity of the star
- Whether the star is isolated or in a multiple star system
- The differing initial composition of the stars
- The different masses of the stars
- The strength of the magnetic fields in the stars

27 Theories about the effects of radiation have changed over the years. Suppose you are preparing a report on the most current scientific views on the subject. While searching for reference books, you find a book titled *Radiation and You*. Which piece of information should you use to determine if this book will be a useful source for your research?

- the copyright date
- if “hazardous effects” is in the index
- whether the U.S. Energy Commission has approved it
- whether pioneering scientists are quoted in it

28 Which of these is a hypothesis that can be tested through experimentation?

- Bacterial growth increases exponentially as temperature increases.
- A fish’s ability to taste food is affected by the clarity of aquarium water.
- Tadpoles’ fear of carnivorous insect larvae increases as the tadpoles age.
- The number of times a dog wags its tail indicates how content the dog is.
This graph contains information about the motion of a bicycle. At which of the following times is the bicycle’s acceleration zero?

- [ ] at 1 second
- [ ] at 2 seconds
- [ ] at 4 seconds
- [ ] at 8 seconds
APPENDIX B

PRE-EXAM

Name:___________________________________     Date:_________________

please print your name

Astronomy Village

Pre-exam

Instructions
Read the following items carefully and mark the box next to the response that best answers the question.

Pre-exam

1  Stars and Galaxies give off
   □ a variety of types of electromagnetic energy
   □ only visible light
   □ only radio waves
   □ only UV radiation

2  A beam of white light that passes through a prism
   □ produces a reduced image
   □ produces an enlarged image
   □ separates into all of its colors
   □ does not change
3 Arrange the following three types of waves in order from lowest frequency to highest frequency

- X-rays, visible light, gamma rays
- gamma rays, visible light, X-rays
- gamma rays, X-rays, visible light
- visible light, gamma rays, X-rays
- visible light, X-rays, gamma rays

4 Many science textbooks report that our sun is “burning out” and will eventually become cold. Students from a science class carefully observed the sun for a one-week period and could not detect any changes in the sun. The most probably explanation for this lack of observable change is that

- the textbooks are wrong and the sun is not burning out
- the changes in the sun are too small to observe over as short a time period as one week
- the students were only observing the sun during daylight hours.
- the sun gives off equal amounts of light even though it is slowly burning

5 Astronomers use Cepheids principally as measures of what?

- size
- speed
- chemical composition
- distance
Why isn’t parallax used to measure the distance to Andromeda, our nearest neighbor large galaxy?

☐ Parallax can only be used to measure the distances to distant objects, where the small angle approximation works.

☐ Parallax relies on main sequence stars, and there aren’t any main sequence stars in Andromeda

☐ Parallax can only be used on nearby objects, because if the objects are distant it is difficult to measure the angles accurately

☐ Parallax requires a bright, individual star, and there are no stars bright enough in Andromeda to use this method

☐ Parallax requires an excellent view, and Andromeda is obscured by so much dust and gas we can’t see it

Scientists have been able to find no atmosphere around this planet because it has little gravity and is closest to the sun. The planet described is:

☐ Mercury

☐ Earth

☐ Venus

☐ Saturn

An astronomer measured the distance between two stars. The distance the astronomer recorded was probably measured in

☐ light years

☐ centimeters

☐ tons

☐ inches

Our sun will explode as a supernova in about 4 or 5 billion years

☐ True

☐ False
10 The Sun produces energy by fusing hydrogen into ________ in its core.
   □ carbon
   □ helium
   □ iron
   □ oxygen

11 Which of the following belongs with the group below: WHITE DWARF, SUPERGIANT, NEUTRON STAR
   □ asteroid
   □ planet
   □ Supernova
   □ galaxy

12 The sun’s energy output remains constant over time
   □ True
   □ False
Using the diagram below, which of these stars has completed its life cycle?

- Black dwarf
- Supergiant
- Main-sequence star
- Red giant
## APPENDIX C
### CURRICULAR OUTLINES

<table>
<thead>
<tr>
<th>Unit</th>
<th>Day</th>
<th>Activity</th>
<th>Relevant National Standards</th>
<th>Relevant QCC Standards</th>
<th>Relevant AKS Standards</th>
<th>Required Materials</th>
</tr>
</thead>
</table>
|      | 1   | Stellar Nurseries Overview 1 (20 min)  
Navigating through the Village and Statement of Problem  
*Path Diagram, Background Research  
Auditorium: Star Forming Regions (10 min)  
Library, Article: The  
Electromagnetic Spectrum (30 min)  
Library, Article: Multi-Wavelength Astronomy (20 min)  
Hands on Lab: The Visible Spectrum and Beyond (20 min)  
Thought Question (10 min) | Primary:  
IV. Know the range of the Electromagnetic spectrum.  
IV. Know that waves have energy and can transfer energy when they interact with matter. | 24.1 Identifies the use of probes, satellites, light and radio telescopes, and spectroscopes to gather information about space.  
14.11 Demonstrates dispersion of white light into a color spectrum and the addition of primary colors to form white light  
14.0 Labels the eight sections of a chart of the electromagnetic spectrum.  
1.1 Designs and conducts a scientific experiment that identifies a problem, distinguishes manipulated, responding and controlled variables, collects, analyzes and communicates data, and makes valid inferences and conclusions. | Primary:  
~explain the tools and techniques to observe the universe (SCAS_B2003-20)  
(20a)  
~investigate early methods of observation of the cyclical pattern of the celestial bodies (QCC) (SCAS_A2003-3)  
(3b1) | glass prism, incandescent light, fluorescent light, thermometer with resolution to a tenth of a degree |
|      | 2   | Stellar Nurseries Overview 2 (20 min)  
Image Processing software and Hands-on activity  
*Path Diagram: Data Analysis  
Computer Lab, Image Processing  
Computer: Counting Objects and Creating a Composite Image Exercises (30 min)  
Path Diagram: Data Interpretation  
Hands on Lab: The Milky Aquarium (30 min) | Secondary:  
IV. Know ways in which technology has increased our understanding of the universe | | |
|      | 3   | Students individually complete Activity-Oriented Quiz #1 and collaboratively review quiz responses with Answer Explanations | | | |
|      | 4   | | | | | |
|      | 5   | | | | | |
## Curricular Outline for Week Two

<table>
<thead>
<tr>
<th>Unit</th>
<th>Day</th>
<th>Activity</th>
<th>Relevant National Standards</th>
<th>Relevant QCC Standards</th>
<th>Relevant AKS Standards</th>
<th>Required Materials</th>
</tr>
</thead>
</table>
|      | 1   | Search for Nearby Stars Overview 1 (20 min) Navigating through the Observatory and Statement of Problem  
Path Diagram, Background Research  
Auditorium: Searching for Nearby Stars (10 min)  
Library, Article: The Brightness of Stars (15 min)  
Library, Article: Distances to Nearby Stars (15 min)  
Observatory, View Selected Stars and Constellations (20 min) | 5.1 Demonstrates the relationship among the various means of measuring distances in space.  
5.4 Observes the motion of the stars located close to the celestial equator.  
21.1 Describes features, characteristics, and motions of the planets. | Primary  
III. Knows characteristics and movement patterns of the nine planets in our Solar System  
Secondary  
II. Knows that the Earth is one of the several planets that orbit the Sun, and the Moon orbits around the Earth.  
IV. Knows that evidence suggests that our universe is expanding  
III. Knows that many billions of galaxies exist in the universe. | Primary  
~define, measure, and compare distances in space as well as terrestrial distances using accepted methods and units (QCC)  
(SCAS_A2003-2) (2e1)  
~describe stellar motion (QCC)  
(SCAS_B2003-14) (14a)  
~name and describe the inner planets (SCAS_B2003-11) (11b)  
~name and describe the outer planets (SCAS_B2003-13) (13a)  
~compare and contrast the motion of celestial bodies (QCC)  
(SCAS_B2003-12) (12d)  
~investigate early methods of observation of the cyclical pattern of the celestial bodies (QCC)  
(SCAS_A2003-3) (3b1) | Ruler, string, tape, cardboard, styrofoam balls, scissors, glue, baseball diamond, baseball bat, paper, notebook, marker. |
|      | 2   | Search for Nearby Stars Overview 2 (10 min) \Path Diagram: Background Research  
Library, Article: Grand Tour of the Universe (20 min)  
Hands on Lab: How to Visualize Parallax (20 min)  
Hands on Lab: A Three-Dimensional Star Field (25 min)  
Path Diagram: Data Interpretation  
Thought Question (10 min)  
Path Diagram: Data Analysis  
Computer Lab, Image Processing Computer: Making a Movie to look for Parallax Exercise (20 min) |  | Secondary  
II. Knows that the Earth is one of the several planets that orbit the Sun, and the Moon orbits around the Earth.  
IV. Knows that evidence suggests that our universe is expanding  
III. Knows that many billions of galaxies exist in the universe. |  |  |
|      | 3   | Search for Nearby Stars Overview 2 (10 min) \Path Diagram: Background Research  
Library, Article: Grand Tour of the Universe (20 min)  
Hands on Lab: How to Visualize Parallax (20 min)  
Hands on Lab: A Three-Dimensional Star Field (25 min)  
Path Diagram: Data Interpretation  
Thought Question (10 min)  
Path Diagram: Data Analysis  
Computer Lab, Image Processing Computer: Making a Movie to look for Parallax Exercise (20 min) |  | Secondary  
II. Knows that the Earth is one of the several planets that orbit the Sun, and the Moon orbits around the Earth.  
IV. Knows that evidence suggests that our universe is expanding  
III. Knows that many billions of galaxies exist in the universe. |  |  |
<p>|      | 4   | Students individually complete Activity-Oriented Quiz #2 and collaboratively review quiz responses with Answer Explanations |  |  |  |  |
|      | 5   |  |  |  |  |  |</p>
<table>
<thead>
<tr>
<th>Unit</th>
<th>Day</th>
<th>Activity</th>
<th>Relevant National Standards</th>
<th>Relevant QCC Standards</th>
<th>Relevant AKS Standards</th>
<th>Required Materials</th>
</tr>
</thead>
</table>
|      | 1   | Variable Stars Overview 1 (10 min) Statement of Problem  
Path Diagram, Background Research  
Auditorium: Variable Stars (10 min)  
Library, Article: Variable Stars (15 min)  
Library, Article: Candles to Light the Night (30 min)  
Thought Question (10 min)  
Path Diagram: Data Interpretation  
Hands on Lab: Cepheid Variable Interpretation Guide (30 min) | Primary | 5.1 Demonstrates the relationship among the various means of measuring distances in space. Standard 1.0 Uses science process skills in laboratory or field investigations, including observation, classification, communication, metric measurement, prediction, inference, collecting and analyzing data.  
1.1 Designs and conducts a scientific experiment that identifies a problem, distinguishes manipulated, responding and controlled variables, collects, analyzes and communicates data, and makes valid inferences and conclusions | | | |
|      | 2   | Variable Stars Overview 2 (10 min)  
Path Diagram: Data Analysis  
Computer Lab, Image Processing  
Computer: Studying Cepheids and Light Curves (30 min)  
Hands on Lab: Constructing a Light Curve (45 min) | Primary | IV. Know common characteristics of stars in the universe.  
4. Uses technology (e.g., hand tools, measuring instruments, calculators, computers) and mathematics (e.g., measurement, formulas, charts, graphs) to perform accurate scientific investigations and communications | | | |
|      | 3   | | | | | |
|      | 4   | | | | | |
|      | 5   | Students individually complete Activity-Oriented Quiz #3 and collaboratively review quiz responses with Answer Explanations | | | | |

Primary ~define, measure, and compare distances in space as well as terrestrial distances using accepted methods and units (QCC) (SCAS_A2003-2)(2e1)  
Secondary ~use traditional reference materials, the Internet, and available software to research astronomy topics (QCC) (SCAS_A2003-1) (1b1)
<table>
<thead>
<tr>
<th>Unit</th>
<th>Day</th>
<th>Activity</th>
<th>Relevant National Standards</th>
<th>Relevant QCC Standards</th>
<th>Relevant AKS Standards</th>
<th>Required Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Search for a Supernova</td>
<td></td>
<td></td>
<td>Primary ~explain the characteristics of our sun, including location, apparent movement, distance from Earth, and impact on Earth (QCC) (SCAS_B2003-8) (8c) ~explain the life cycle and energy source of stars (QCC) (SCAS_B2003-15) (15a, 15c, 15c1, 15c2, 15c6) ~investigate early methods of observation of the cyclical pattern of the celestial bodies (QCC) (SCAS_A2003-3) (3b1)</td>
<td>Primary ~explain the characteristics of our sun, including location, apparent movement, distance from Earth, and impact on Earth (QCC) (SCAS_B2003-8) (8c) ~explain the life cycle and energy source of stars (QCC) (SCAS_B2003-15) (15a, 15c, 15c1, 15c2, 15c6) ~investigate early methods of observation of the cyclical pattern of the celestial bodies (QCC) (SCAS_A2003-3) (3b1)</td>
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<td>2</td>
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<td>Search for a Supernova Overview 2 (30 min)</td>
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<td>Path Diagram: Data Collection</td>
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<td>Hands on Lab: Neutrino Data</td>
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<td></td>
<td></td>
<td>Path Diagram: Data Analysis</td>
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<tr>
<td></td>
<td></td>
<td>Computer Lab, Image Processing</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>Computer: Studying Brightness of Stars</td>
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<tr>
<td></td>
<td></td>
<td>Path Diagram: Data Interpretation</td>
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<tr>
<td></td>
<td></td>
<td>Thought Question</td>
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<tr>
<td></td>
<td></td>
<td>Path Diagram: Presentation Thought Question</td>
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<tr>
<td>4</td>
<td></td>
<td>Students individually complete Activity-Oriented Quiz #4 and collaboratively review quiz responses with Answer Explanations</td>
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<tr>
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</tbody>
</table>
APPENDIX D

STATEMENT OF PROBLEM

As a member of the Nearby Star Research Team, your investigation will focus on this question:

"Has a previously undetected nearby star been discovered?"

As part of your investigation, you will conduct background research to be aware of the kinds of stars that are found in our stellar neighborhood and learn how distances to nearby stars are measured.

During the data collection stage of your investigation, you will make telescopic observations of two regions of the sky that might contain nearby stars.

Your team will then be ready for data analysis. You will compare your observations with ones previously taken to determine if a star has shifted position among the background stars.

During the data interpretation step of your investigation, your team will determine the distance to any stars that displayed a shift and draw conclusions based on your findings.

And finally, once your team has completed its investigation, you will present your findings to a press conference and, after the press conference, to your peers and teacher.
Log Book: Searching for Nearby Stars

Team Name: ________________________________________

Team Members: ________________________________________
____________________________________________________________________________
____________________________________________________________________________

Teacher: ________________________________________

Period: ________
**Note:** You must save this RTF document as an application-specific file (for example, MyLog.doc in Microsoft® Word).
### Searching for Nearby Stars
#### Investigation Checklist

<table>
<thead>
<tr>
<th>Background Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditorium: Dr. Todd Henry's Lecture</td>
</tr>
<tr>
<td>Library: The Brightness of Stars</td>
</tr>
<tr>
<td>Library: Distances to Nearby Stars</td>
</tr>
<tr>
<td>Library: A Grand Tour of the Universe</td>
</tr>
<tr>
<td>Hands-On Lab: A Three-dimensional Starfield</td>
</tr>
<tr>
<td>Hands-On Lab: How to Visualize Parallax</td>
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</table>

<table>
<thead>
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<th>Observatory</th>
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</thead>
<tbody>
<tr>
<td>Computer Lab</td>
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<th>Data Collection</th>
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<tbody>
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<td>Observatory</td>
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<table>
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<th>Data Analysis</th>
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<tbody>
<tr>
<td>Computer Lab</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Data Interpretation</th>
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</thead>
<tbody>
<tr>
<td>Computer Lab</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thought Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presentation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Press Conference</th>
</tr>
</thead>
</table>
Searching for Nearby Stars

Statement of Problem

As a member of the Nearby Star Research Team, your investigation will focus on this question:

"Has a previously undetected nearby star been discovered?"

As part of your investigation, you will conduct Background Research to become aware of the kinds of stars that are found in our stellar neighborhood and to learn how distances to nearby stars are measured.

During the Data Collection stage of your investigation, you will make telescopic observations of two regions of the sky that might contain nearby stars. Your team will then be ready for Data Analysis. You will compare your observations with ones previously taken to determine if a star has shifted position.

During the Data Interpretation stage of your investigation, your team will determine the distance to any stars that displayed a shift and draw conclusions based on your findings.

And finally, once your team has completed its investigation, you will present your findings at a press conference and, after the press conference, to your peers and teacher.
Searching for Nearby Stars
Statement of Problem

Background Research

Data Collection

Data Analysis

Data Interpretation

Presentation
Auditorium: Dr. Todd Henry’s Lecture, “Searching for Nearby Stars”

Main Idea
Write 3 sentences about the main idea of this lecture.

Importance
Write one sentence about how this lecture helps in your investigation. This lecture was important because…

Further Questions
Write down unanswered questions that you may still have about this topic. From this lecture, I (we) still wonder about…
Searching for Nearby Stars - Background Research

Library: The Brightness of Stars

Main Idea
Write 3 sentences about the main idea of this article.

Importance
Write one sentence about how this article helps in your investigation. This article was important because…

Further Questions
Write down unanswered questions that you may still have about this topic. From this article, I (we) still wonder about…
Searching for Nearby Stars - Background Research
Name________________________________  Date_______________________

Library: Distances to Nearby Stars

Main Idea
Write 3 sentences about the main idea of this article.

Importance
Write one sentence about how this article helps in your investigation. This article was important because…

Further Questions
Write down unanswered questions that you may still have about this topic. From this article, I (we) still wonder about…
**Searching for Nearby Stars - Background Research**

Name________________________________ Date_______________________

**Library: A Grand Tour of the Universe**

**Main Idea**

Write 3 sentences about the main idea of this article.

**Importance**

Write one sentence about how this article helps in your investigation. This article was important because…

**Further Questions**

Write down unanswered questions that you may still have about this topic. From this article, I (we) still wonder about…
Searching for Nearby Stars - Background Research

Name________________________________  Date_______________________

**Hands-On Lab: A Three-dimensional Starfield**

Observations: When you stand underneath and look straight up at the 3-D model of Ursa Major, the familiar dipper shape will look as it does in the night sky.

1. What happens to this shape if you move to the right or left and view the stars from different angles?

2. If you lower the height of the model and view it from the edge, will the stars shift position in relation to each other?
**Hands-On Lab: How to Visualize Parallax**

A. Using a magic marker, number five sheets of paper from 1 through 5. Make sure that the numbers are large enough to be seen from the outfield to home plate on a baseball field.

B. Distribute the numbered sheets to five student volunteers. Ask them to form a row - in numbered order - across the outfield. Have them hold the numbered sheets up so you can see the numbers as the experiment is conducted. (See Figure 1 below).

C. Ask a sixth student volunteer to stand on the pitcher's mound.

D. Stand at the left side of home plate (as a right-handed batter) and point the bat at the pitcher. Look past the pitcher and record the number that appears closest to the pitcher.

E. Stand at the right side of home plate (as a left-handed batter) and point the bat at the pitcher. Look past the pitcher and record the number that appears closest to the pitcher.
F. If the experiment were to be repeated with the pitcher standing at second base, would the "shift" be different? How?

Record your comments in the space provided below.
**Searching for Nearby Stars - Data Collection**

Name________________________________  Date_______________________

**Observatory: Image Browser**

- Look at these stars: Alpha and Proxima Centauri and Sirius A and B. You can find them in the "Stars" category of the Browser.

- View the familiar star patterns of Ursa Major, Orion (Full View), Cygnus, Gemini, and Scorpius in the "Constellations" category.

- Select and draw two or three images you will use to illustrate your presentation at the end of the investigation.
Searching for Nearby Stars - Data Collection
Name________________________________  Date_______________________

Computer Lab: 3D Star Simulation

Use this page to record your observations of the constellations Cassiopeia, Orion and the
Big Dipper and how they look when viewed from other locations in space.
**Searching for Nearby Stars - Data Collection**

Name________________________________  Date________________________

**Observatory: Master Control Computer**

We have been photographing the two regions for the past twelve months, at three-month intervals. Your team will take a current set of images. The images that you should take are:

- **Cygnus Sky Region**
  - Right Ascension ____________________
  - Declination ________________________

- **Eridanus Sky Region**
  - Right Ascension ____________________
  - Declination ________________________

Record the queue name and queue number(s) for your observations here:

____________Queue

Queue # ___________________________
Queue # ___________________________  

Record comments about your observations in the space below.
Searching for Nearby Stars - Data Analysis
Name________________________________  Date________________________

Computer Lab: Image Processing Computer
Did your data analysis help you to determine if a star has shifted position relative to the background stars? How? Use examples from your image processing to explain your answer.
Searching for Nearby Stars - Data Interpretation

Name________________________________  Date________________________________

Computer Lab: Image Processing Computer

How far away is the star that your team located? What impact does your interpretation of the data have on answering your research question?
Searching for Nearby Stars - Data Interpretation

Thought Experiment

If remote-controlled telescopes were placed on Mercury and Pluto, would it be easier or more difficult to discover nearby stars from these planets? Would the parallax shift of a nearby star be different when viewed from Mercury or Pluto? To help arrive at your conclusions, here are some facts to consider:

<table>
<thead>
<tr>
<th>Planet</th>
<th>Distance from Sun in millions of kilometers</th>
<th>Period of revolution around the Sun in Earth time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>57.9</td>
<td>88 days</td>
</tr>
<tr>
<td>Earth</td>
<td>108.2</td>
<td>1 year</td>
</tr>
<tr>
<td>Pluto</td>
<td>5,900</td>
<td>248 years</td>
</tr>
</tbody>
</table>
Press Conference
If we lived inside a globular cluster, where the stars are much closer together than they are in our local neighborhood, would we find more or fewer stars with measurable parallax? Explain your answer.

Is our Sun a fairly typical neighborhood star? What other kinds of stars are found in our local neighborhood, and how many of them are there?

What do you think the likelihood is that the next nearby star discovered will be like our Sun? Why?
How are nearby stars identified and the distance to them from the Earth calculated? Why doesn't this technique work for all stars?

Explain why nearby stars are difficult to detect. In your explanation, comment about the relationship between brightness and distance.

Describe the research model used at the Astronomy Village. In your judgment was the model a useful way to organize your investigation?
APPENDIX F

ACTIVITY-ORIENTED QUizzes

Name: __________________________________   Date: ______________________

please print your name

Astronomy Village

Quiz 1

Instructions

The following items ask questions about the activities you completed in Astronomy Village this week. Answer each item in the space provided and be prepared to discuss your explanations.

Quiz

1a Write the following components of the Electromagnetic Spectrum in order from higher energy to lower energy waves: X-Rays, UV, Infrared, Radio, Gamma, Visible Light, and Microwave. Write the appropriate wave under each line.

|                       |           |           |                 |               |           |

1b As you move down the Electromagnetic Spectrum, the energy level decreases. What happens to the wavelength as you move along the spectrum from high to low energy?

2 Why are astronomers interested in making observations in the non-visible part of the spectrum? Is there really anything out there worth knowing that we cannot see?
Astronomy Village
Quiz 2

Instructions
The following items ask questions about the activities you completed in Astronomy Village this week. Answer each item in the space provided and be prepared to discuss your explanations.

Quiz
1a  When you look up at the Big Dipper, all the stars appear equally bright. Are they at equal distances from the Earth?

1b  Explain why or why not.

2a  An astronomer is gazing at two stars in the night sky. He wants to see which of the two stars is closer to the Earth, so he measures their parallax. He finds that star 1 has a parallax of 0.5 seconds of arc, while star 2 has a parallax of 0.2 seconds of arc. Which of the two stars is closer to the Earth?

2b  Explain your choice.
Astronomy Village
Quiz 3

Instructions
The following items ask questions about the curricular activities you have just completed. Answer each item in the space provided and be prepared to discuss your explanations.

Quiz
1a  What is a Variable Star?

1b  What are the characteristics of Cepheid variable stars that make them useful as distance indicators?

Example of Cepheid light curve
Astronomy Village
Quiz 4

Instructions
The following items ask questions about the curricular activities you have just completed. Answer each item in the space provided and be prepared to discuss your explanations.

Quiz
1  Using what you learned in the Hands on Lab “Supernova Core Collapse,” and the Lecture “What is a Supernova,” use the basic process that is going on in all stars to determine if our Sun will experience a Supernova and explode. In your answer, describe what astronomers think is the life cycle of a star like the Sun.

2a  Examine the data below. Does the data indicate that a recent supernova event may have occurred?

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DUMAND: 100, 250, 500, 800, 1000, 1200, 1650, 1900, 2100(seconds)

IMB - OHIO: 200, 350, 900, 1650, 2000, 2500, 2600(seconds)

KAMIOKANDE: 375, 500, 700, 1000, 1350, 2100, 2800(seconds)

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2b  Explain your answer.
APPENDIX G

REVIEW ROUTINE STEPS

FOR EACH QUIZ AND EXAM ITEM

1. **EXPLAIN AND COMPARE EACH ANSWER:**
   Everybody should share what they wrote earlier and explain why they wrote it or how they knew.

2. **REACH INITIAL CONSENSUS:**
   The group should try to agree on the most sensible solution, or agree to disagree. Everyone should understand why one (or more) answers are sensible.

3. **REVIEW ANSWER EXPLANATION:**
   As a group, read aloud the answer explanation sheet. Use the written explanation and the language of science to agree on the most sensible solution.

4. **CONFIRM GROUP UNDERSTANDING:**
   Everyone should understand and agree with a final sensible solution. Take your time. It’s more important that everyone understands, than to finish quickly. Also, consider why the item was written in the first place.
Labeled directly from the article “The Electromagnetic Spectrum,” the components of the spectrum going from high energy to low energy waves are Gamma, X-Rays, UV, Visible Light, Infrared, Microwave, and Radio. The Electromagnetic Spectrum is divided into the seven components according to wavelength. As you move down the spectrum, energy decreases, but the wavelength increases. Energy is inversely proportional to the wavelength. "Inversely proportional" means that as one gets smaller the other gets larger. Therefore, the shorter the wavelength, the greater the energy of the EM wave. Gamma rays, which have very short wavelengths, are the most energetic, and radio waves, which have very long wavelengths, are the least energetic.

It is very important to be able to label and understand the importance of each component of the Electromagnetic spectrum because if you remember from the reading, you often see and use each of the components in your everyday life. For example, you see visible light, you use Microwaves to heat up your dinner, and when you lay by the pool in the summer, you wear sunscreen to block UV rays.

The EM spectrum is also very important in astronomy because it is our only means of studying the universe outside our solar system. The visible part of the spectrum, which is all things seen with the unaided eye, will only reveal a limited amount of what is out in space. In fact, if astronomers had their choice of observing only visible light or the rest of the EM spectrum, they would probably choose the rest of the spectrum. By observing and measuring energy in all parts of the spectrum, astronomers can uncover secrets of the universe that are completely invisible to the human eye. EM waves of all wavelengths are being emitted from stars, supernovae, nebulae, and many other objects in space. For example, newly star forming...
regions release infrared and UV waves, pulsars emit radio waves, supernovas emit X-Rays, and Black Holes emit Gamma rays. So, clearly, we can see that in order to investigate processes such as star formation and interstellar clouds, it is necessary to observe space at different wavelengths.

In addition, the Electromagnetic Spectrum is not only important for astronomers, but for other professions as well. For example, doctors use gamma rays in radiation treatments of cancer and psychologists and optometrists use visible light when studying vision and perception. How do you think that radiologists and physicists make use of the EM spectrum? As you can see, the Electromagnetic Spectrum plays a major part in all our lives, and will continue to play an important role in your studies.
Naturally, you might think that brighter stars appear brighter because they are close to us. Actually, stars come in many sizes, colors, and degrees of brightness. Some of the stars that appear very bright (apparent magnitude, which is how bright a star appears) may actually be very far away.

Some Supergiant stars are hundreds of thousands of times brighter than our Sun. The faintest stars are only a fraction of the brightness of the Sun. But when you look up into the night sky, the faint star may look brighter than the Supergiant star. Therefore, how bright a star appears to us depends on both its intrinsic brightness (how bright it really is) and its distance. This means that astronomers can’t rely on brightness to estimate distances to stars, thinking that if a star is brighter, it must be closer.

Therefore, when you look up at the Big Dipper, all the stars appear equally bright and of equal distances away from the Earth. However, they are not at equal distances from the Earth. The reason is that the stars that are more intrinsically bright are further away than the stars that are less intrinsically bright. Therefore, as you have seen in your lab “3D Star Fields,” the Big Dipper has stars that look equally bright from Earth, but just have differences in distance that make up for the different degrees of brightness. As a result, all the stars in the Big Dipper look as if they are at equal distances from the Earth.

Although astronomers cannot rely on brightness to measure distances to stars, they can use the concept of Parallax to determine how distant a star is from the Earth. An astronomer can look at two different stars in the sky and see that one shows a great degree of parallax, while another shows a very small amount or even an unmeasurable amount of parallax. From the lecture, we learned that parallax depends on distance, with nearer objects showing greater parallax than more distant objects. Furthermore, very distant objects show no parallax. Therefore, stars with a greater degree of parallax are closer to the Earth than stars with a much smaller degree or no degree of parallax.

To help you get a better understanding of this, think back to the article “Distances to Nearby Stars.” Hold your finger a few inches from your face and look past it at distant objects. When you quickly close one eye and then the other, your finger appears to change position or "shift" when compared to the objects in the background, because each eye is viewing the object from a slightly different position. Nearby stars also experience the same shift. However, if you hold your finger farther away from your face, you will see that this shift is much smaller than when you held your finger close to your face. So you can see how distant stars show smaller, or even no shift, and are often used as background reference points since they don't shift.

It is very important to remember that your eyes represent the Earth at two different positions as it rotates around the Sun and your finger represents the star which seems to shift as the Earth rotates around the Sun.
Take a look at this picture and think of your left eye as Earth-Position 1 and your right eye as Earth-Position 2. As the Earth moves around the Sun, the nearby star seems to shift. When you are at Earth-Position 1, the star seems to be shifted to the right, and when you are at Earth-Position 2, the star seems to be shifted to the left. But if the star is very far away it will show a very small, or almost no shift. Do you understand why this shift in the stars, or parallax, helped astronomers like Copernicus and Kepler prove that the Earth is revolving around the sun?
In the lecture “Variable Stars,” Dr. Pompea defined variable stars as “stars that change their brightness.” When you go out the night sky, most of the stars in the night sky don't change their brightness noticeably. However, some stars brighten or dim over a few years, months, days, or even seconds. These unusual stars are called variable stars, and give us important clues on how stars live and die, and may give us the key to measuring the distances to other galaxies.

A Cepheid Variable star is a type of star that changes its brightness in a distinctive and regular way. Because of its regularity in brightness changes, it is more easily studied than variable stars with irregular periods (such as Supernova). If you remember from the Hands on Lab “Constructing a Light Curve,” most Cepheids will have similar light curves. (A light curve is used in this case to show the regular pattern in brightness of Cepheid Variable stars. However, similar sorts of graphs/charts are used to check for other sorts of patterns. One example is a doctor checking for an irregular heartbeat on a graph). Therefore, we can identify distant stars as Cepheids and feel sure that we are truly observing a Cepheid.

Cepheids are so bright we can see them at the edge of our galaxy. The Hubble Space Telescope can see Cepheids in galaxies that are quite a distance away. If you measure how much fainter a distant Cepheid is compared to a nearby one, you can determine the relative distance between the two. So you can compare the differences in brightness between two Cepheids to figure out the distances between two galaxies. So, these Cepheids are quite a fantastic find!

Often in a math or science problem, you will be given an equation or a problem where you will have to find one variable. For example, if you are told in a physics class that $F=ma$, and you have a value for $F$ and a value for $M$, then you can work with the equation to find out the value for $A$. This is what astronomers are doing when working with Cepheid Variable stars. By using what they know about Cepheids being so distinctive, they can compare the brightness between two of them to figure out the part of the problem they don’t know—the distances between two Cepheids which will give the distance between two galaxies.
Astronomy Village
Quiz 4
ANSWER EXPLANATIONS

1. The Sun is a star, and in the center of all stars, there is a nuclear bomb going off. (Remember this bomb is going off in all stars in a process known as nuclear fusion—which is hydrogen turning into helium). And when you imagine a nuclear bomb going off, you imagine this huge explosion where stuff is flying out in all kinds of directions. So what's keeping this stuff from our own Sun from blowing apart into a thousand pieces? What's holding the Sun together in the presence of this nuclear bomb going off in the center is gravity.

In fact, throughout a star's life there is a constant tug of war between gravity, which is constantly trying to squeeze the star down to the smallest possible size, and this nuclear bomb going off in the center of the star, which is trying to make the star explode. Throughout most of the life of the star, which is about ten billion years for our own Sun, it is a stalemate with both sides tugging as hard as they can, but neither side moving very much.

But this cannot last forever. Eventually, the Sun is going to run out of hydrogen. So what's going to happen then? When it runs out of hydrogen, the nuclear fusion slows down for a little while or eventually stops. Gravity starts to win this tug of war because there is not this bomb going off in the center as there was before. Gravity causes this star to shrink down and get smaller, and it causes the center of the star to heat up.

If you were to take a tennis ball and start compressing it in your hand, you would eventually find that the tennis ball gets hot. That is also what happens in the center of the Sun. In fact, it eventually gets so hot, it is able to burn helium into carbon. So the Sun is actually able to burn its own ash, and another generation of a nuclear explosion... begins. This re-ignites the fire of the Sun and causes gravity to stop compressing the star, and once again there is a tie in this tug of war.

Eventually, the star will reach a point where its central temperature is not hot enough to burn the ash past nuclear reactions. In such an instant the central fire -- the central bomb -- goes out. There is now no bomb going off in the middle to balance the pull of gravity. It's as if one team in the tug of war suddenly lets go of the rope, and the other team rushes forward into a pile of mud. Gravity causes the star to rush in on itself.

What happens next depends on the mass of the star. If the star is less than about eight times the mass of the Sun (this includes the Sun), the contraction will be stopped by the pressure of all the electrons piled up together in the center of the star. (Remember, an atom is composed of three basic atomic particles: electrons, protons and neutrons.) In the case of a star that's about eight times the mass of the Sun or less, what will stop the contraction is the electrons crowding together. Once the collapse has stopped, a star that was originally the size of the Sun has shrunk down to about the size of the Earth!

Now, all the mass that was in that star is being compressed into a little body about the size of the Earth, so it's incredibly dense. During this process, no supernova occurs. What happens instead is that the star slowly loses its outer envelope of gas, so all that's left is what is known as a little white dwarf at the very center.

2. If you remember back to the lab “Neutrino Data,” Neutrino detectors are used to help determine if a supernova has occurred. When a Supernova occurs, it generates and releases many
trillions of neutrinos, some of which reach Earth. Astronomers have neutrino detectors that are used to detect neutrinos to help determine if a Supernova has occurred.

For example, below is a chart from the lab that shows spike occurrence data from three detectors that have been plotted to allow an easy comparison of occurrences. Most of the spikes occurred at only one, or possibly two detectors. However, two sets of spikes occurred at the same time at all three detectors (the numbers 350 and 2600 seconds). This is good evidence that these particular spikes were caused by neutrino bursts, not noise. If direction data were available, the next step would be to use a telescope to search for evidence of a supernova out in space. However, on your quiz question, were there ever three numbers that occurred at all three of the detectors? If there were then you could say that a Supernova event may have occurred, if not, then the detectors probably just picked up noise or some other type of interference.

| DUMAND: 100, 350, 500, 800, 1000, 1200, 1650, 1900, 2600 (seconds) |
| IMB-Ohio: 200, 350, 900, 1650, 2000, 2500, 2600 (seconds) |
| Kamiokande: 350, 500, 700, 1000, 1350, 2100, 2600 (seconds) |

Again, you can see the importance of charts and technology in helping us understand space. You will be using charts, graphs, and technology throughout your academic career in all areas of learning, and one day in your future job.
APPENDIX I

QUESTIONNAIRE

• Of all the activities in the path diagram, which did you decide to do and why?
• Of the activities, which did you enjoy the most?
• Which of the activities really helped you learn the topics in the investigation?
• Did using the logbooks help you in any way? How and why?
• Did you ever take the CD home and use it? If yes, did you use it to review, catch up on what you couldn’t complete in class, or just spend time going through different parts of the CD for fun?
• On a scale of 1 to 5 (with 1 being not at all important and 5 being very important), how important is it to you to have a high score on this four week astronomy curriculum?
• On a scale of 1 to 5 (with 1 being I don’t understand at all, and 5 being completely understand), how well do you understand the investigation you just completed?
• On a scale of 1 to 5, did this whole new way of doing science (with 1 being not at all more interested and 5 being much more interested), help you become more interested in learning science?
• Did the discussion of the feedback answers within your group help you get a deeper understanding of the material? Explain why or why not and give instances where it helped and did not help.
• On the next investigation, will you do anything differently? List what you would do differently.
APPENDIX J

POST-EXAM

Name: _____________________________________     Date: ___________________

please print your name

Astronomy Village
Post-exam

Instructions
Read the following items carefully and mark the box next to the response that best answers the question.

1. Stars and galaxies give off
   □ a variety of types of electromagnetic energy
   □ only visible light
   □ only radio waves
   □ only UV radiation

2. A beam of white light that passes through a prism
   □ produces a reduced image
   □ produces an enlarged image
   □ separates into all of its colors
   □ does not change

3. Arrange the following three types of waves in order from lowest frequency to highest frequency
   □ X-rays, visible light, gamma rays
   □ gamma rays, visible light, X-rays
   □ gamma rays, X-rays, visible light
   □ visible light, gamma rays, X-rays
   □ visible light, X-rays, gamma rays
4 The graph below represents the brightness and temperature of stars visible from Earth.

Which location on the graph best represents a star with average brightness and temperature?

(1) A  (3) C
(2) B  (4) D

5 Astronomers use Cepheids principally as measures of what?

☐ size
☐ speed
☐ chemical composition
☐ distance

6 Why isn’t parallax used to measure the distance to Andromeda, our nearest neighboring galaxy?

☐ Parallax can only be used to measure the distances to distant objects, where the small angle approximation works.
☐ Parallax relies on main sequence stars, and there aren’t any main sequence stars in Andromeda
☐ Parallax can only be used on nearby objects, because if the objects are distant it is difficult to measure the angles accurately
☐ Parallax requires a bright, individual star, and there are no stars bright enough in Andromeda to use this method
☐ Parallax requires an excellent view, and Andromeda is obscured by so much dust and gas we can’t see it
7  Saturn is the only planet in our solar system with rings.
   [ ] True
   [ ] False

8  An astronomer measured the distance between two stars. The distance the astronomer recorded was probably measured in
   [ ] light years
   [ ] centimeters
   [ ] tons
   [ ] inches

9  Our sun will explode as a supernova in about 4 or 5 billion years
   [ ] True
   [ ] False

10 The Sun produces energy by fusing hydrogen into _________ in its core.
    [ ] carbon
    [ ] helium
    [ ] iron
    [ ] oxygen

11 Which of the following belongs with the group below: WHITE DWARF, SUPERGIANT, NEUTRON STAR
    [ ] asteroid
    [ ] planet
    [ ] Supernova
    [ ] galaxy

12 The sun’s energy output remains constant over time
    [ ] True
    [ ] False
Using the diagram, which of these stars has completed its life cycle?

□ Black dwarf
□ Supergiant
□ Main-sequence star
□ Red giant
APPENDIX K

EXAM ANSWER EXPLANATIONS

Astronomy Village

Exam

ANSWER EXPLANATIONS

1. When studying space, astronomers use all of the components of the electromagnetic spectrum to see parts of the universe that would normally be invisible to the human eye. Electromagnetic waves of all wavelengths are being released from stars, supernovae and other objects in space. For example, newly star forming regions release infrared and UV waves, pulsars emit radio waves, supernovas emit X-Rays, and Black Holes emit Gamma rays.

2. Prisms separate white light according to the wavelengths of visible light included in white light. Do you know the colors that make up the visible part of the spectrum? Is this the only part of the spectrum that we can see with the unaided eye?

3. As you move down the spectrum from Gamma Rays to Radio Waves, the energy decreases, but the wavelength increases. Energy is inversely proportional to the wavelength. This means that as the energy of the wave decreases, the wavelength increases. However, wavelength is also inversely proportional to frequency. So as the frequency increases, the wavelength decreases. So Gamma rays, which have very short wavelengths and very high frequencies, are the most energetic component of the electromagnetic spectrum.

4. Did you get this question right for the wrong reasons? You are looking for a star with an average brightness and temperature. The average relates to the data, not just the scales. Therefore consider the relationship or distribution of the data points, not the middle of the chart (between hot and cool on the temperature scale and between dim and bright on the luminosity scale). Most points lie along a line from the top left corner to bottom right corner. Some points are above and below this line, but they balance out, or cancel each
other out. Therefore, you would look along the spectrum of Main Sequence stars and find that most stars lie along that line. If you were to average the stars along the Main Sequence stars, a star with an average brightness and temperature would fall on the line of stars, a little below option B. Because B is the closest and most reasonable choice, you should select B. However, looking at the middle of the graph (an incorrect way to consider average) also suggests that B is the answer … for the wrong reason.

5 A Cepheid Variable star is a type of star that changes its brightness in a unique and regular way. Because the changes are a distinct pattern, we can identify distant stars as Cepheids and be sure that we are truly observing a Cepheid. Measuring how much fainter a distant Cepheid is compared to one nearby reveals the relative distance between the two. This kind of measurement enables astronomers to compare the differences in brightness between two Cepheids in two different galaxies to determine the distances between the two galaxies.

6 Parallax depends on distance. Nearer objects show greater parallax than more distant objects. Very distant objects show no parallax at all. As a result, parallax will only be useful in measuring the distance to nearby objects. Although Andromeda is our nearest neighboring galaxy, it remains too distant to measure accurately using parallax angles.

7 It is often thought that Saturn is the only planet with rings. However, this is untrue. We now know that Jupiter, Uranus, and Neptune also have them. What else do these four planets have in common?

8 In space, the distances between stars, planets, and even galaxies are enormous and require an appropriate measurement scale. For example, units such as centimeters and inches that would be used for small scale measurements such as the length of your pencil would not be useful for measuring the distance from your high school to the University of Georgia. For larger scale distances like this, miles or kilometers are appropriate. By the same logic, measuring astronomical space requires units of an even larger scale measurement. Therefore, astronomers use light years (the distance that light can travel in a year). Finally, the unit of Tons is used for weight and not distance.

9 The center of the sun is constantly undergoing nuclear fusion, where hydrogen fuses into helium. It is like a nuclear bomb going off in the sun. At the same time however, gravity works to squeeze or compact the star to a smaller size. As hydrogen dissipates over billions of years, fusion will slow, allowing gravity to increasingly “crush” the sun but, instead of collapsing, electrons will only crowd together because of the size of the sun. Therefore the sun will neither explode nor collapse, but rather shrink into a white dwarf.

10 Stars like the sun generate energy through nuclear fusion of hydrogen and helium. This transformation of energy keeps stars from squeezing down under the pressure of gravity. The core of the Sun is also constantly going through nuclear fusion, producing energy by turning hydrogen into helium.

11 A White Dwarf, Supergiant, and Neutron Star are all different types of stars at different points in their life cycles. The only other star in the answer choices is a Supernova.
The Sun will eventually run out of energy during its process of nuclear fusion, and will then shrink down. When the Sun begins to shrink, the electrons that crowd together will stop the collapse, and the Sun will be compressed into a white dwarf.

Stars do not remain constant over time. Like the Sun, all stars go through a life cycle as their energy output changes over time. As can be seen on the diagram, the only stars that have come to the end of their life cycle and cannot be changed into another type of star include the Black Dwarf, Neutron Star, and Black Hole.
APPENDIX L

ACTIVITIES AND FEEDBACK CONVERSATIONS ANALYZED FOR STRATEGY USE, CONCEPTUAL UNDERSTANDING
AND SELF-REGULATION
The tables below include all of the suggested activities and all of the feedback conversations for the four-week implementation. Each activity or feedback conversation that was analyzed for strategy use, conceptual understanding, and self-regulation are marked in the table. The overviews were not suggested activities, but were introductory classroom discussions introducing students to the software and activities. In addition to what is marked on the table, self-regulation was also calculated by summing the number of activities students completed in the logbooks each week.

<table>
<thead>
<tr>
<th>Week One</th>
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<tbody>
<tr>
<td>Unit</td>
</tr>
<tr>
<td>Stellar Nurseries</td>
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<tr>
<td>Auditorium, Lecture: Star Forming Regions</td>
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<tr>
<td>Library, Article: The Electromagnetic Spectrum</td>
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<td>Library, Article: Multi-Wavelength Astronomy</td>
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<td>Hands on Lab: The Visible Spectrum and Beyond</td>
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<tr>
<td>Thought Question</td>
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<tr>
<td>Computer Lab, Image Processing Computer: Counting Objects and Creating a Composite Image Exercises</td>
</tr>
<tr>
<td>Hands on Lab: The Milky Aquarium</td>
</tr>
<tr>
<td>Feedback Conversation: Students individually complete Activity-Oriented Quiz #1 and collaboratively review quiz responses</td>
</tr>
</tbody>
</table>

Note. Neither the males nor females completed the thought question activity this week. Although there were three activities within the logbook that could be analyzed for problem solving strategies this week, both the males and females completed only two of these three activities. Therefore, only two activities within the logbook were analyzed for problem solving strategies.
<table>
<thead>
<tr>
<th>Unit</th>
<th>Activity</th>
<th>Strategy Use</th>
<th>Conceptual Understanding</th>
<th>Self-regulation</th>
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<tbody>
<tr>
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<td><strong>(Search for Nearby Stars Overview 1: Navigating through the Observatory and Statement of Problem)</strong></td>
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<td>Library, Article: The Brightness of Stars</td>
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<td>Library, Article: Distances to Nearby Stars</td>
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<td></td>
<td>Observatory, View Selected Stars and Constellations</td>
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<td></td>
<td><strong>(Search for Nearby Stars Overview 2)</strong></td>
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<td>Library, Article: Grand Tour of the Universe</td>
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<td></td>
<td>Hands on Lab: How to Visualize Parallax</td>
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<td>Hands on Lab: A Three-Dimensional Star Field</td>
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<td>Thought Question</td>
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<td></td>
<td>Computer Lab, Image Processing Computer: Making a Movie to look for Parallax Exercise</td>
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<td>Feedback Conversation: Students individually complete Activity-Oriented Quiz #2 and collaboratively review quiz responses</td>
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<td>Library: Article: Variable Stars</td>
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<tr>
<td>Library, Article: Candles to Light the Night</td>
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<td>(Variable Stars Overview 2)</td>
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Note. Although there were three activities within the logbook that could be analyzed for problem solving strategies this week, both the males and females completed only two of these three activities. Therefore, only two activities within the logbook were analyzed for problem solving strategies.
### Week Four

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<th>Conceptual Understanding</th>
<th>Self-regulation</th>
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</tr>
<tr>
<td></td>
<td><strong>Overview 1: Statement of Problem</strong></td>
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<tr>
<td>Auditorium, Lecture: What is a Supernova?</td>
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<td>Observatory, View Selected Images</td>
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<td>Hands on Lab: Supernova Core Collapse</td>
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<td><strong>Overview 2</strong></td>
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<td>Hands on Lab: Neutrino Data</td>
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<td>Computer Lab, Image Processing Computer: Studying Brightness of Stars</td>
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<td>Thought Question</td>
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<tr>
<td>Feedback Conversation: Students individually complete Activity-Oriented Quiz #4 and collaboratively review quiz responses</td>
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Note. Logbooks were not collected for the fourth week, so conceptual understanding and strategy use were assessed only through the feedback conversations over the quizzes.